To my old friend and colleague James Nuttall,
whose enthusiasm and labour in the cause
of Practical Education has inspired a generation
of students, teachers, and craftsmen.

The E.H.A. *Series*

OF HANDBOOKS ON
SCHOOL ARTS & CRAFTS

General Editor:
STEWART TAYLOR

METALWORK

FOR SCHOOLS & COLLEGES
ITS PRINCIPLES & PRACTICE

by

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General Editor's Note.

THE E.H.A. represents the pioneer movement in this country for the advancement of Handwork Methods of teaching. It continues to be the premier organisation both in this respect and in its work of training teachers in those methods. This latter function it accomplishes through its Summer Schools on the one hand and the numerous classes and courses organised by its branch associations on the other; while for more than a quarter of a century, first by its association with the Board of Examinations for Educational Handwork, and latterly entirely on its own account it has published detailed syllabuses of Examination in more than 20 branches of Educational Handwork, conducted examinations and issued qualifying certificates to successful candidates in these subjects.

To many of us therefore it seems that the time has arrived when all this ripe experience ought to be placed within the reach of those who find themselves unable to take advantage of self-improvement and certification by attendance at our classes and courses. The printed book presents an opportunity to serve our colleagues; hence the appearance of this series.

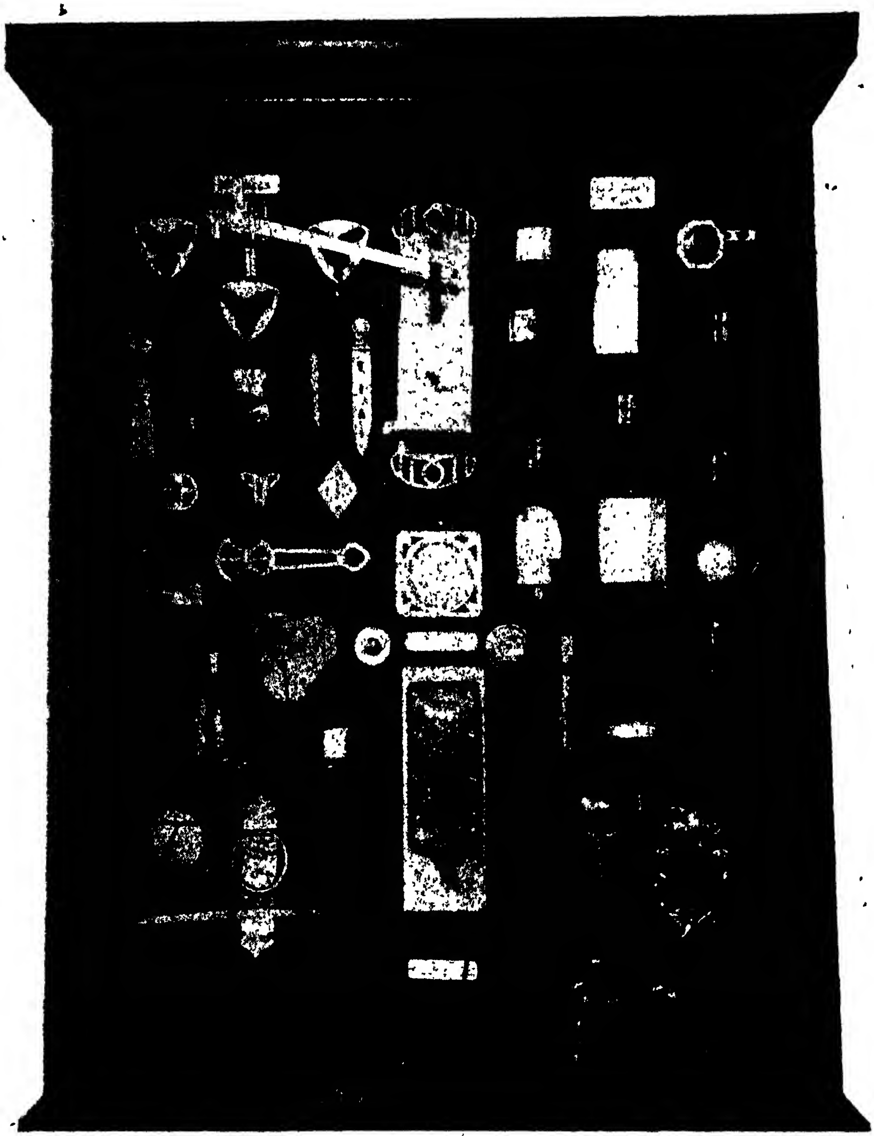
In the main, this book is an elaboration of the syllabus published by the E.H.A. Examinations Board. Thus it is expected to prove of the highest value to students preparing for our Examinations. But it also contains the essential matter of an appropriate school and college course, and as such, cannot fail to be of the utmost value to those who have charge of Metalwork courses, as well as those under their instruction.

Metalwork is above all else a technical subject. That is no reason, however, why its educational possibilities should be overlooked where it is taught in our Secondary, Senior and Central Schools. Both aspects of the matter have been kept well in view and in this respect the book strikes a distinctly new note.

Further, it has been the belief of many in our Association that Metalwork teaching has not emerged from the swaddling clothes in which it was conceived. One of the main reasons for this is due to the fact that there was no modern text-book on the subject, or one that dealt with the modern outlook towards the subject. This book has been written to supply that deficiency, and in our opinion it amply justifies its belated appearance.

S.T.

Handcraft in Metal.



A COURSE OF WORK.

Author's Preface.

THE time seems not far distant when provision for instruction in Metalwork will be the complement of every modern school equipment. Already in many of the newer schools the subject is firmly established, and by the time the recommendations of the Hadow Report are generally adopted, Metalwork as an educational activity will occupy its rightful place among the school crafts.

The widespread interest on the part of students and teachers in this phase of handicraft has created an undoubted need for a book which forms a general survey of the different branches of metalcraft, and it is for the purpose of supplying this need that the present work has been prepared.

The aim of this humble treatise is educational, inasmuch as it is intended to develop an appreciation and knowledge of general principles rather than encourage empirical methods and schemes of work. In each branch of a very wide subject the simplest types of construction have been dealt with at considerable length, and the principles they embody have been demonstrated and emphasised. A long experience has confirmed the opinion that a student who has grasped the fundamental facts of any subject requires a minimum of guidance in its more advanced stages. The tendency, which is excused in many handicraft rooms, on the ground of expediency, to depart from traditional methods and resort to " make-shifts " finds little support in these pages. The author is convinced that unless due regard is paid to right methods and craft tradition in even the earliest stages of metalwork, no scheme can be educationally sound, as it results in loose thinking, and in a student having to unlearn at a later stage in his training.

Students preparing for the examinations of the City and Guilds of London and the Educational Handwork Association will find the requirements of both these examining bodies covered by the text, but the hope is expressed that in addition to its use as an examination manual, the work, on which a large amount of thought and labour have been expended, may be of service to all grades of teachers in extending their knowledge and craftsmanship, and in assisting them to combine theory and practice.

In conclusion the author has to acknowledge his indebtedness to Mr. Stewart Taylor for much kindly advice in preparing the work for the press, and to Mr. S. Thorn and Mr. R. Stead of the Handicraft and Engineering Department, City of Leeds School, for their valuable assistance in experimenting with many of the suggestions contained in the text, and bringing them to a successful issue.

GEORGE J. ARMYTAGE.

CITY OF LEEDS SCHOOL,
1929.

Preface to Fourth Edition.

The publication of this new edition presents the opportunity for the author to acknowledge gratefully the kindly recognition still given to this work, and to avail himself of the many helpful suggestions put forward for improving its scope. Several alterations have been made in the text, and additions have been made to the sections on organisation, forge work, and decorative metalwork.

The section on " raising " has been entirely rewritten, and courses of work have been suggested within the ability of the average handicraft student, and to meet the requirements of examination candidates.

The appendix has been brought up to date by including the most recent question papers of the City and Guilds of London, and the E.H.A. Examinations Board.

1939. GEORGE J. ARMYTAGE.

CONTENTS.

CHAPTER I.

Introduction.

TWO developments, which will have an important bearing on the curriculum of the senior departments of an Elementary or Modern School, seem likely to arise in the near future, viz., the lengthening of the school life of the pupils, and an increased emphasis in the growing demand that the training given should involve a more direct preparation for both life and livelihood.

Both of these should result in a further impetus to practical work in education, while metalwork will undoubtedly be a prominent feature in any scheme put forward. There is a growing feeling that work in this material provides the best means not only to the cultivation of technique in educational handwork, but to a broadening out of the syllabus along vocational lines—if that be desired.

This awakening interest has been of slow growth. Many prejudices and misconceptions have conspired to retard it, and no criticism has had a more adverse effect, than the two entirely false views that metalwork is a very costly business, and that the work is beyond the physical capabilities of boys in elementary schools. To show how tenaciously prejudices of this kind cling it has to be remembered that these two had their origin in the late "eighties," and have remained with us until quite recently.

Co-incident with the introduction of Woodwork in 1888, Metalwork was attempted in a few schools, but lacking the guidance and enthusiasm of a Salomon, the experiment was not a success. In the main the teachers had been recruited from engineering establishments, brought up amongst heavy plant, and, as we should naturally expect, with the outlook of the expert craftsman rather than that of the teacher. Any possible usefulness that metalwork might contribute to a scheme of educational training was not made evident, and so, many of its advocates abandoned the idea of its introduction into elementary schools.

It has taken nearly forty years to wipe out the errors of a false start, and to eradicate the false judgment then hastily arrived at.

During this time many teachers have added light metalwork to their woodwork schemes, others have demonstrated the possibilities of metalcraft allied to art, whilst a few have persevered with the type we are now concerned with. In all probability the force of circumstances brought about during the war did more to focus attention on metalwork than anything that had happened previously. The difficulty then experienced of obtaining other material was overcome very largely by making a fuller use of metal, and if the scope of the work was limited by reason of lack of equipment and fuller knowledge, the costly scheme fetish at least was exposed, and the appeal of this purposive work to early adolescence became generally recognised.

There is now every indication that with a revival of educational activity greatly increased facilities for metalwork in schools will be granted, and the object of this treatise is to draft out a rational scheme within the capacity of boys in the higher classes of elementary and central schools, and with an equipment which will be found to compare favourably, as regards initial cost and maintenance, with the outlay required for an efficient woodwork centre. No attempt will be made to present model courses of work. Such pieces of work as are described will be used merely as being illustrative of some principle under discussion, the most successful courses being those determined by the varying conditions under which the teacher works, and which apply to the needs of different types of schools.

The method adopted in the teaching of metalwork must be influenced by the character of the school, *i.e.*, whether it is senior or central, rural or urban, but the fundamentals are the same for all types. Our pupils will leave us in varying stages of proficiency, and our aim should be to teach on such sound lines that any subsequent addition to the knowledge gained would be built up on a sure foundation. In this contribution to the subject no more ambitious attempt will be made than to get down to the bedrock principles underlying the intensely interesting practice of educational metal-work.

AIM OF THE COURSE.

i. To provide further opportunity in Senior, Central, Secondary and Junior Technical Schools for the acquirement of manipulative skill and sound technique.

ii. To develop the powers of imagination and artistic expression, and particularly the inventive and creative faculties.

iii. To extend a general outlook on the materials and products of a Metal age, and to provide scope for the study of the application of scientific principles underlying the construction of machines and tools most generally used.

iv. Generally to stimulate a spirit of craft pride which can only be truly appreciated through personal skill and accomplishment.

BRIEF OUTLINE OF COURSE.

Metalwork introduces a pupil not only to a greater variety of material, but also to a greater number of processes in the working of them than any other branch of handicraft.

So numerous are these processes that they have been classified into six groups : each group constituting a separate trade :—Fitting, Turning, Smith's-work, Art Metalwork, Sheet Metal and Metal Plate Work, and Moulding and Casting.

In a well equipped metal work-room provision should be made for work in all these branches, and the Scheme we are about to describe will include the following :—

(*a*) Fitting.—Exercises including chipping, filing, drilling, tapping, screwing, rivetting, brazing, and general vise work.

(*b*) TURNING.—Centring, turning between centres and in chucks, hand turning, sliding, surfacing, boring, screw-cutting, taper turning.

(*c*) FORGE-PRACTICE.—Drawing down, upsetting, twisting, annealing, case-hardening, hardening and tempering.

(*d*) ART METALWORK. — Piercing, repoussé, raising, hard and soft soldering, making up and finishing, etching.

(*e*) SHEET METALWORK. — The development of surfaces, folding, forming, soldering, rivetting, wiring, jointing.

(*f*) MOULDING AND CASTING. — The making of simple patterns, contraction and " draw " allowances, flask moulding in green-sand, use of cores, making of core-boxes, casting in lead, type metal and aluminium.

(*g*) SCIENCE HANDICRAFT.—Almost every boy attending a metalwork course will also be studying some branch of natural science, probably Mechanics and Physics, and every opportunity will be taken of co-ordinating the work of the two courses.

ORGANISATION OF SCHEME.

The ideal training for a boy, preparatory to commencing metalwork, is a two years' course of woodwork. During this period he will have acquired a sound knowledge of mechanical drawing and have learnt to appreciate the value of accurate graphic representation : he will have a fair degree of hand skill and be able to express himself intelligently in the material he is acquainted with. Further, the plan of approach to new problems presented to him, learnt by patient effort under the direction of sound teaching, will be invaluable to him when confronted with totally new processes, much more resistant material, and the harnessing of forces, other than his own muscular power, to do mechanical work.

The step from woodwork to metalwork is a natural one and should be the system adopted in a thorough Handicraft Scheme. If no facilities for woodwork exist in close proximity to the metalwork room, a bench fitted with a vise and woodworking tools should be included in the equipment, as the combined use of both materials will be often required.

Metalwork classes are sufficiently large with sixteen pupils, and the session should not exceed two hours and a half of continuous work. With allowances for holidays this gives a yearly total of about one hundred and ten hours, small enough surely to pacify any critic who may fear wholesale " dilution " of the metal working trades.

With a class of beginners it is advisable to commence with eight students on vise work, four on forge work, and the rest divided between sheet-metal work and lathe practice.

By adopting this system, equipment may be reduced to a minimum, only the tools required by each group being necessary.

Getting familiar with tools and processes will occupy a considerable portion of a pupil's first year, and, as in woodwork, until this familiarity is attained, the work must, in the main, be of a disciplinary character if real progress is to be made.

A good arrangement for smooth working is to allow each group of boys to remain on the same kind of work for three months, and then to change over.

At the end of twelve months every boy will have acquired a good experience over a wide range of operations, and then he might be allowed to determine to what purpose his knowledge shall be applied.

This method will be found to produce better results than by allowing a pupil to be changing continually about from vise to forge and back again, before he has become at all skilled in either aspect of metalcraft.

Demonstrations and group lessons will be frequently necessary, and class lessons should be given as occasion demands, *e.g.*, on the properties of materials, care and use of machines, cutting speeds, etc.

The accommodation for turning and moulding being limited, boys will take their turn as machine or bench becomes vacant.

Throughout the whole course a high standard of craftsmanship should be demanded, the work never being allowed to become merely recreational.

DRAWING.

A working drawing should precede all practical work. This need not necessarily be complete at the commencement of a project, but should contain sufficient information to show that a student is familiar with the general aspect of his work, and has a definite plan of action in his mind. Details may be added and the drawing completed as the work progresses.

As the majority of students taking this Course will have had some experience with projection, scale, and isometric drawing, both in the class-room, and in the handicraft room, it is reasonable to expect a good standard of draughtsmanship at this stage.

Where Technical Drawing is a special subject in a school course, and boys are able readily to make and interpret working drawings, the use of blue-prints may be generally adopted, thus enabling the whole of the workshop period to be devoted to practical work. This applies particularly to Scheme No. III.

To secure uniformity of practice between school and industry all working drawings should be prepared in accordance with the recommendations of the British Standards Institution Report No. 308.

At the end of a year a boy should be able to make and read a working drawing, and to work accurately to a 1/200 of an inch with a file: he should be capable of shaping a piece of wrought iron to requirements, and drawing down, hardening and tempering a cutting or punching tool. The development, folding up, and jointing of simple objects based on geometrical forms should be within his power. His knowledge of machines, whilst not being extensive, should be such that he can understand the elementary principles of mechanism. Furthermore the accumulation of his experiences should have developed in him that spirit of craft-pride which industry needs as much to-day as at any period of its history.

Syllabus of Instruction based on 42 sessions of $2\frac{1}{2}$ hours each, per annum.

SCHEMES OF WORK. No. I.

A scheme of Benchwork (fitting practice) and Sheetmetal work, suitable for a room equipped only for these branches of Metalcraft, and outlining a course for a class of 20-24 boys taking woodwork and metalwork in the same room and at the same time. Each group spends one year at each subject.

Term	Benchwork Disciplinary Exercises	Suggested Projects	Sheetmetal work Disciplinary Exercises	Suggested Projects
First	Filing a straight edge. Accurate measuring. Marking out for drilling and chipping. Drilling practice. Chipping $\frac{1}{16}''$ and $\frac{1}{8}''$ plate, holes and contours. Rivetting, Screwing, Tapping.	Escutcheon and name plates. Latch and catch plates and fittings. Bolts and clips Leg and shelf Brackets. Caddy spoons.	(Geometrical) Development of surfaces. Bending. Lapping. Beading. Groove-seaming. Flanging an edge. Soft soldering.	Domestic and culinary utensils. Scoops. Trays. Liquid Measures. Application of P.P & S. Geometry.

MATERIAL :—Mild steel, Bright, $\frac{1}{8}''$ thick.
do., Black, 1", $\frac{3}{4}''$
$\frac{1}{2}'' \times \frac{1}{8}''$
Sheet Iron, No. 16 gauge.
Sheet Brass, No. 16 gauge.
Tinplate, No. IXX.

Second	Cold bending, or with heat from blow-pipe. Surfacing. "Finish" of edges and contours. Piercing. Silver soldering and Brazing. Use of abrasives in obtaining quality of surface.	Stands, Trivets Door Bolts, Box and Drawer handles. Small tools, Soldering bits, etc. Gardening tools, trowels, etc. Mechanisms.	(Decorative). Preservation of stakes, hammer faces, and surfaces of copper. 'Raising' a convex or concave surface. Silver soldering. Pickling, 'Raising' on blocks and stakes, and by coursing. Annealing, Colouring, and Polishing.	Serviette rings. Trays. Bowls. Boxes.

MATERIAL :—Mild Steel, Bright, $\frac{3}{8}''$ and $\frac{1}{4}''$ sq.
Mild steel, black, $\frac{3}{16}''$, $\frac{1}{4}''$, and $\frac{5}{16}''$ diam.
Wrought Iron $\frac{1}{2}'' \times \frac{1}{4}''$
Copper rod, $\frac{5}{8}''$ sq.
Cast steel $\frac{1}{2}'' \times \frac{1}{16}''$
Brass rod and strip of small section.
Copper, half-hard No. 20 gauge.
Copper strip $\frac{5}{8}'' \times \frac{1}{8}''$

Third	More specialised work in either branch, or composite work in both. The selection of each piece, suggestions for design, and practical processes to be an individual effort on the part of each pupil.

SCHEME OF WORK. No. II.

A scheme of Metalwork comprising Benchwork and Fitting Practice, Lathework, Sheetmetalwork, and Forging capable of being carried out in a well-equipped school workshop.

Each class of 16-20 boys divided into three groups A, B, C, one of which will take Vise-work and Fitting for a term, another Sheetmetalwork, and a third, Forging. At the end of each term the groups will change, and commence a fresh set of disciplinary exercises in a different branch of metalwork.

Lathework and Turning Practice will be taken during the Fitting Term, and boys will occupy machines in turn as they become vacant.

Term	Group	Disciplinary Exercises.	Suggested Projects.
First	A. Bench and Lathe Work.	See Scheme No. 1. Turning between centres. Turning in chucks. Taper-turning. Hand-turning for curved shapes. Screw-cutting. Boring.	Pins, Spindles, Handles. Poker-stands, Knobs. Centre-punch. Plumb-bob. Turned parts of work in Fitting Practice. Set-screws and Bolts.

MATERIAL :—Brass rod, $\frac{7}{8}''$, $\frac{3}{4}''$, $\frac{1}{2}''$ diam.
Mild steel, bright, $\frac{3}{4}''$, $\frac{1}{2}''$ diam.
Cast steel $\frac{1}{2}''$ octagonal.
Brass castings, sizes as required.

Term	Group	Disciplinary Exercises.	Suggested Projects.
	B. Sheet-metal work.	See Scheme No. 1.	
	C. Forging	Drawing down. Upsetting. Twisting, Flaring, Fullering and Swaging. Welding (Faggot-weld). Hardening, Tempering, Annealing.	Staples. Hooks. Stands. Trivets, Gong Brackets. Door handles and Knockers. Fire-tongs, Poker, Fire-screens. Small Tools, e.g. Punches, scribers, cold chisels, gardening tools.

MATERIAL :—Mild steel, black, $\frac{1}{4}''$, $\frac{5}{16}''$, $\frac{3}{8}''$ sq.
do. $\frac{1}{4}''$, $\frac{5}{16}''$, $\frac{3}{8}''$ round.
do. $\frac{1}{2}'' \times \frac{1}{8}''$
do. $\frac{5}{8}''$ and $\frac{1}{2}'' \times \frac{1}{4}''$
Wrought Iron $\frac{3}{8}''$ and $\frac{1}{2}''$ sq.
Cast steel $\frac{3}{16}''$ and $\frac{1}{4}''$ sq. and round.
do. $\frac{1}{2}''$ octagonal.

Term	Group	Disciplinary Exercises.	Suggested Projects.
Second	A. B. C.	Forging. Benchwork and Fitting. Sheetmetalwork.	Turning as opportunity arises.
Third	A. B. C.	Sheetmetalwork. Forging. Benchwork and Fitting.	Turning, as above.

N.B.—If the course extends to a second year, the work will be specialised in one of the 3 sections, or it will embrace the whole, the student being allowed reasonable freedom of choice in the course he wishes to continue and the things he desires to make.

SCHEME OF WORK No. III. Based on 42 whole day sessions per annum.

A Scheme of Workshop Practice for a Central School with an industrial bias, or for a Junior Technical School, the majority of students being assumed to have had one year's experience in metal-craft :—Schemes No. I. or II. The number of students in each class is to be limited to 16, and the equipment is to be adequate for work of a high craft standard to be performed. Machine work will form an important feature of the course for which the following machine tools, which may be regarded as a minimum, will be required :—

2 Screw-cutting lathes 5″ centre. Directly motor-driven.
1 Brass-finisher's lathe 4½″ centre.
1 Pedestal sensitive drilling machine. Belt driven.
1 Bench Drilling Machine. Hand or belt-driven.
1 Hack-saw machine. Belt-driven.
1 Emery grinder and buffing machine.
1 Grindstone.
1 Shearing machine. Hand-driven.
1 Blower for forge and brazing blast. Belt-driven.
1 Shaping machine, 8″ stroke. (J.T.S. equipment only).
1 Milling machine, horizontal, bench-type. (J.T.S. equipment only).

Branch	Exercises and Processes.	Practical Applications.
Fitting and Machine Practice.	Filing. Draw-filing. Use of surface-plate. Scraping. Working to limits of accuracy. Making use of screw-threads for fastenings and adjustments. Drilling and boring in drilling-machine and lathe. Chipping and surfacing castings by hand and shaping machine. Turning, surfacing, and boring in lathe. Milling operations. Cutting and chasing screw-threads. Grinding.	Gauges of various kinds. Small tools :—squares, bevels, calipers, hack-saw frame. Cramps of various kinds. Small screw-jack. Surface gauge. Lathe dogs and carriers. Mechanisms to illustrate principle of Barker's Mill, Watt's and Peaucellier's motions, etc. Small machines and engines, i.e. bench drill, gas engine from castings. Grinding lathe and shaper tools to correct angles.
Forging, Smithy Practice and Foundry Work.	Cutting cold and hot stock. Drawing-out, Bending, Twisting. Fullering, Swaging, Truing-up. Punching, Rivetting. Scarfing, Welding, Lap, Butt and Ring-welds. Annealing. Forging tool-steel. Hardening. Estimation of decalescent point. Treatment of high-speed steel. Pattern-making. Sand-moulding in "Flasks." Casting in type-metal, etc.	Bolts, eye, square-headed hooks, wall, hammock. Door-pulls, Straps, Brackets. Forged parts of tools and fitted work. Gib-headed keys, Links. Punches, scribers, chisels, lathe-tools. Preparation of simple patterns for castings in cast-iron, brass and aluminium to be used in Fitting and Lathe Practice.

N.B.—By arrangement students may be able to visit a foundry where castings from their patterns are being made.

Sheet-metal and Metal-	Development of surfaces. Lapping, beading, seaming, wiring. Soft-soldering. Working in thicker plate. [illegible] corners and laps. [illegible]	Household utensils :—boxes, scoops, funnels, trays. Apparatus : — "Eureka" vessel, Nicholson's Hydrometer, Rain-gauge. Geometrical solids and their inter-[illegible]tions. [illegible] joints [illegible]

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1 Hack-saw machine. Belt-driven.
1 Emery grinder and buffing machine.
1 Grindstone.
1 Shearing machine. Hand-driven.
1 Blower for forge and brazing blast. Belt-driven.
1 Shaping machine, 8″ stroke. (J.T.S. equipment only).
1 Milling machine, horizontal, bench-type. (J.T.S. equipment only).

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Forging, Smithy Practice and Foundry Work.	Cutting cold and hot stock. Drawing-out, Bending, Twisting. Fullering, Swaging, Truing-up. Punching, Rivetting. Scarfing, Welding, Lap, Butt and Ring-welds. Annealing. Forging tool-steel. Hardening. Estimation of decalescent point. Treatment of high-speed steel. Pattern-making. Sand-moulding in "Flasks." Casting in type-metal, etc.	Bolts, eye, square-headed hooks, wall, hammock. Door-pulls, Straps, Brackets. Forged parts of tools and fitted work. Gib-headed keys, Links. Punches, scribers, chisels, lathe-tools. Preparation of simple patterns for castings in cast-iron, brass and aluminium to be used in Fitting and Lathe Practice.

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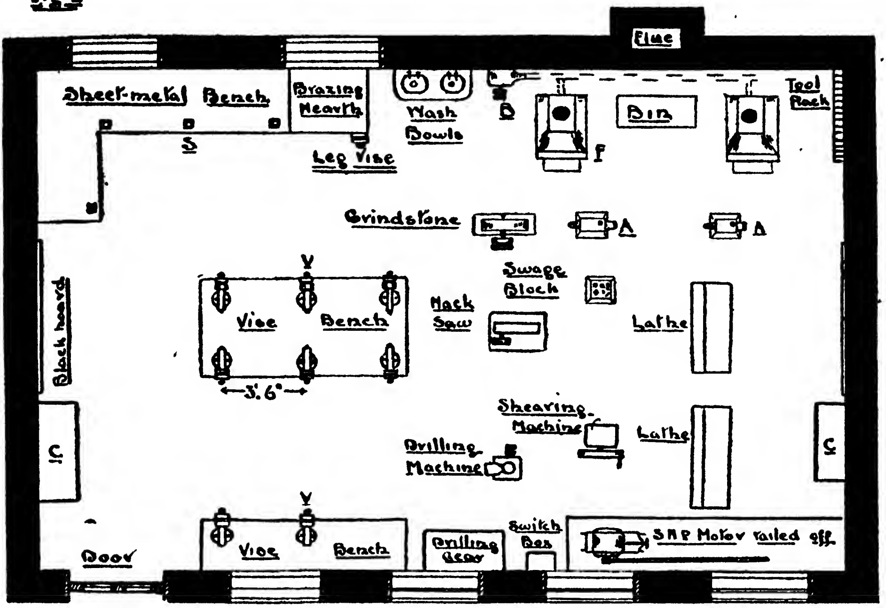
PLAN OF ROOM

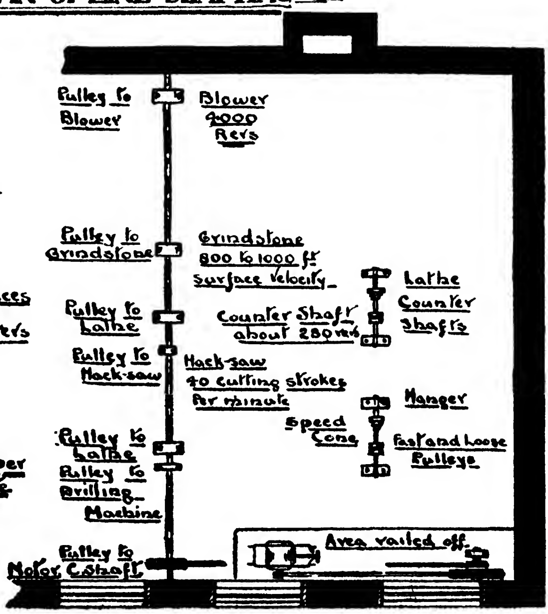
Fig I



A. anvils
B. blowers
C. cupboards
S. sockets
V. Vises

PLAN OF LINE SHAFTING

Fig 2



Motor 3 BHP. Squirrel cage 200 Volts. speed approx. 1400 revs.

The belt drive shown reduces the motor speed to 140 revs of the Main Shaft.

Speeds indicated = Revs. per minute

To what extent machinery should be introduced into the Handicraft room raises a much debated question. Some educationalists contend that the work defeats its own object if mechanical means are allowed to supplant, or even aid manual effort, while the lowering of the standard of craftsmanship, due to the introduction of machinery during the industrial era, is an argument frequently put forward in support of this view.

Even if this were true, which is extremely doubtful, and may only be applicable to some of the wood-working crafts, it is difficult with any experience in the working of metal to see how the introduction of some simple machines can be avoided. The operation of drilling even small holes through a piece of $\frac{1}{8}''$ plate is a long and wearisome process without a machine tool to do it, and interest, a factor that must never be overlooked in the training of a young student, cannot be said to be stimulated by insisting that it shall be done by hand.

A broader view, recognising the educational value and necessity of simple machine tools, considers how far it is advisable to equip metalwork centres with them in order to satisfy the following conditions.

(*a*) The machine can become an additional aid to expression.

Without machine tools, to express his ideas, a boy is restricted to the application of design in either pierced or repoussé work, the educational limits of which are soon reached; or, if more constructionally-minded, he must find an outlet for his ingenuity in the making of working models and mechanical toys from tins and thin sheet metal. In the vise he can file and do some cold bending, but without a drilling machine it is impossible for him to go very far in serious and accurate fitting. A new field is opened to him with the acquisition of a small lathe, especially if it be a screw cutting one, fitted with back gear, etc. The poker handle, Fig. 2A, which before had to be left like A, may now be given any shape his artistic temperament desires, as for instance B, or the button hook C, in a form his sister had to be satisfied with, might now, with these increased facilities evolve itself to look like D, adding infinitely to the pleasure of both the boy and the recipient.

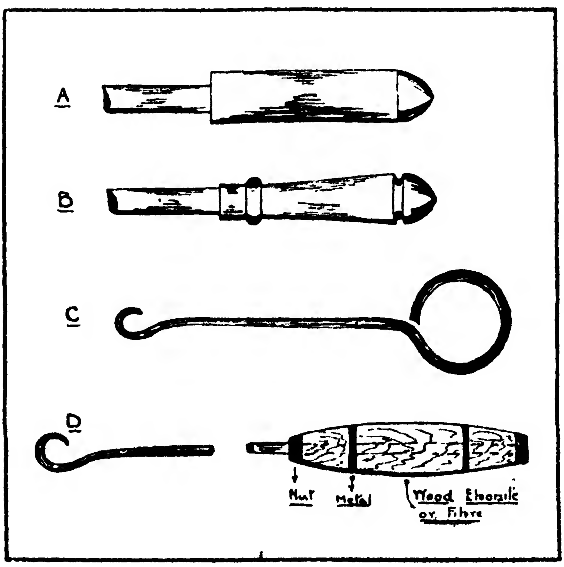


FIG. 2a.

(*b*) The machine can be used as an illustration of mechanical principles.

In that branch of mechanics known as " Machines," a boy learns that the mechanical elements are six in number and fall into two groups :—

1. Lever. Pulley. Wheel and Axle.

2. Inclined plane. Wedge, Screw.

As all machines, no matter how complicated, are combinations of two or more elements, every one added to a metal work centre, apart from its general utility, is a piece of apparatus for demonstrating the application of science to practical use.

Discussions on velocity ratio and mechanical advantage can be held around the machines themselves and problems can be worked out bearing on the relative speeds of pulleys, belt speed, and cutting speed of drills, etc., effect of back gear on the turning effort on a lathe mandril. The merits of positive and non-positive drives with belts and gears can also be demonstrated. Not only is this first hand knowledge, valuable in itself, but the investigation will lead a boy to appreciate the thought and skill of the designer. The machine he is operating is not the result of haphazard construction, but the application of the scientific knowledge he himself is acquiring.

(*c*) The necessity for simple machine knowledge in a modern educational system.

A training in hand skill must always be regarded as one of the fundamentals of schoolcraft, but, as there are many operations which cannot be performed solely by hand, and as modern education seeks to keep a nation abreast of the times, no limitations should be put upon students by withholding necessary tools, machine or otherwise, when there is a real need demanding them.

For reasons quite apart from production, it is very desirable that a boy's knowledge of tool processes should be as comprehensive as possible. The fuller it is, the clearer will be his outlook on the World of Industry which is waiting to absorb him.

Tools change with the adoption of new processes of manufacture, but the general mechanical principles upon which their action depends do not change. The time spent in investigating the principle and action of simple machines will tend to develop a critical attitude, *e.g.*: On what principle is its action based ? What methods are employed in its use ? These are natural questions which will arise when a trained student is confronted with a piece of mechanism : and on their intelligent solution depends the higher productive effort of the student, and his personal satisfaction in his increasing knowledge, factors which all tend to the development of a highly intelligent individual.

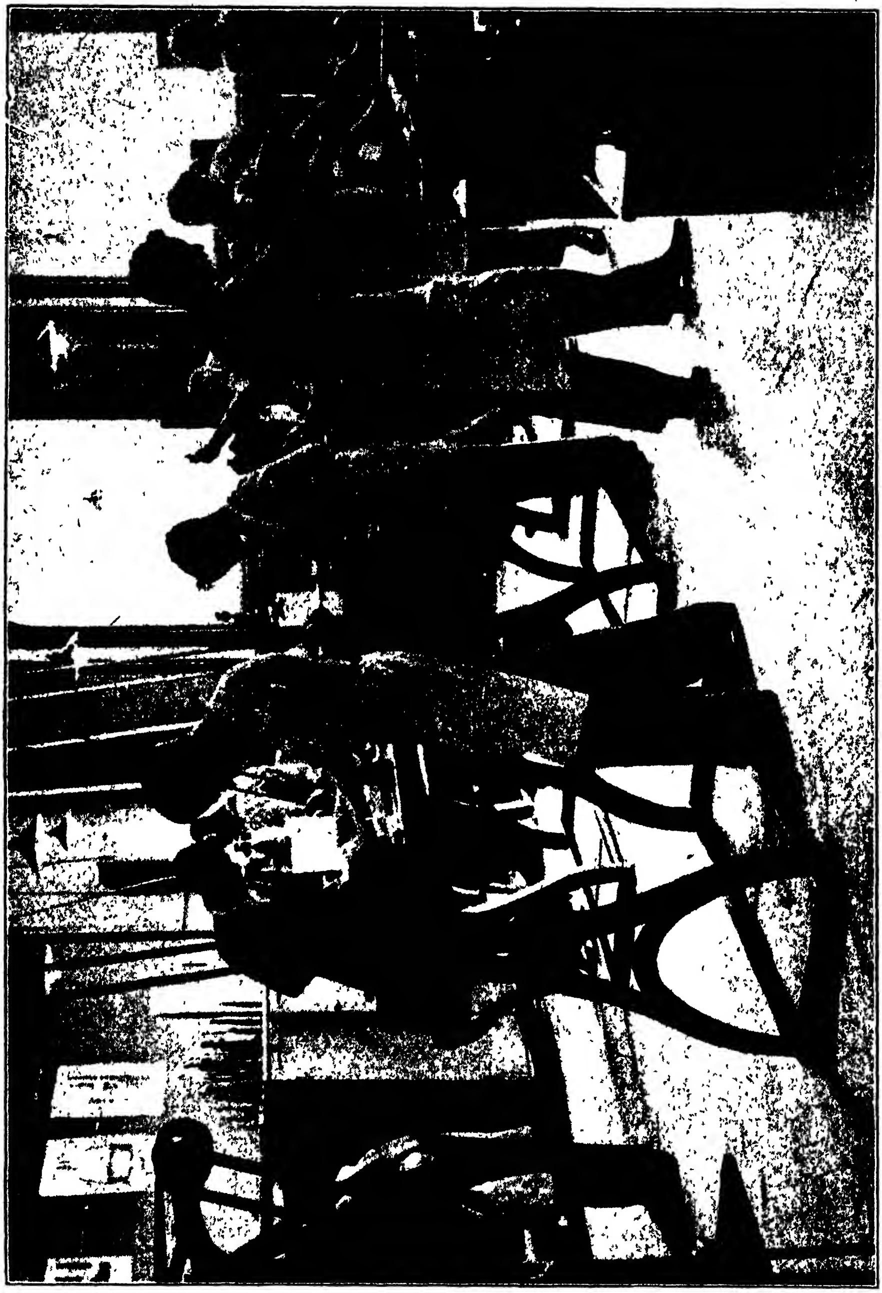


FIG. 3.—A METALWORK CLASS OF 16 STUDENTS.

Fig. 2 shows the plan of the shafting and pulleys necessary for each machine.

The main shaft revolves at 140 revolutions per minute and is driven by a $3\frac{1}{2}$ h.p. electric motor.

Countershafts and striking gear are necessary for each lathe, but all the other machines can be driven direct from the main shaft, each machine having a fast and loose pulley arrangement bracketed to it.

If the brackets carrying the shafting are to be suspended from a ceiling having a room above, they should be insulated with rubber pads to deaden sound and vibration.

DETAILS OF EQUIPMENT AND COSTS.

(*a*) MACHINERY

	£	s.	d.
$3\frac{1}{2}$ h.p. Motor, complete with slide rails and switch gear ..	23	0	0
5″ Centre, screwcutting lathe with countershaft and accessories	50	0	0
$4\frac{1}{2}$″ Centre, brass finishers' lathe with countershaft and accessories	22	0	0
Standard drilling machine, sensitive, complete with chuck, drill up to $\frac{1}{2}$″	12	0	0
Hacksaw machine, 10″ centre	8	0	0
Grindstone in iron trough, 4″ face, spindle fitted with fast and loose pulleys	12	0	0
Two wrought iron forges fitted with blast nozzles and hoods	15	0	0
Blower for the forges, up-discharge, with provision for blast necessary for brazing	10	0	0
Small shearing machine	3	10	0
Main shaft, $1\frac{1}{2}$″, hangers, lubricators, belts, etc.	14	10	0
Motor countershaft	4	0	0
Millwrights' work, including fixing of machines, motor and shafting ; together with sheet iron chimney from hearths to flue, and gasfitting to soldering stove and brazing blow pipe	32	0	0
Joiners' work, including benching, cupboards, etc., and the fixing of these	60	0	0
	£265	0	0

(*b*) SMALL TOOLS.

	£	s.	d.
Vise-work tools and appliances	35	0	0
Forge „ „ „	6	0	0
Lathe „ „ „	6	0	0
Sheet metalwork tools and appliances	9	0	0
Drawing instruments and material	5	0	0
	£61	0	0

(c) SUMMARY OF COSTS.

	£	s.	d.
Machinery, benching, cupboards, etc.	265	0	0
Small tools, etc...	61	0	0
Material for one year	12	0	0
Miscellaneous additional expenses	12	0	0
	£350	0	0

Arrangements for the Care and Upkeep of Equipment.

(a) SMALL TOOLS.

Files.—Kept in drawers fitted with racks:—coarse, second, smooth, assorted, etc. Handles painted different colours to ensure proper replacement and quick checking.

Scribers and Chisels.—Renewals made during smithy practice. Ground as required during lessons.

Drills.—Kept in metal stands, $\frac{1}{16}''$ to $\frac{3}{16}''$ and $\frac{7}{32}''$ to $\frac{1}{2}''$. Breakages to be immediately reported.

Measuring and Marking Tools.—Easy of access. A rack containing each being situated near vise work and sheet metal benches.

Snips.—Those which cannot be ground in the room sent out annually to be ground and set. The same applies to stakes.

Soldering Irons.—After a demonstration on tinning has been given, each boy required to keep his own in condition. New irons made during vise work lessons.

Special Tools.—All kept in racks easily seen and accessible.

New files first used on brass and changed over to steel each half year. This also applies to hack saw blades.

At the end of each lesson all unfinished work labelled and placed in locker or cupboard, tools returned to proper places, and vises, benches, etc., brushed down.

Previous to long vacations, all tools thoroughly overhauled, cleaned, greased, and stored away.

(b) MACHINES.

Motor.—No interference allowed with switch. Ring lubrication supplied with oil weekly.

Shafting.—Fitted with "Louvain" needle lubricators. Only need attention about once a term.

Belting.—Treated with dressing once at end of term. Taken off the pulleys during long periods of rest.

Machines.—All machines to be oiled before use and cleaned down after. All accessories to be put in their proper places.

Grindstones.—It is advisable to have two grindstones. A good broad faced one for broad tools and fine grinding, and an old one which can be used for grinding scribers, punches, etc., otherwise grooving of the better stone is sure to occur.

Repairs.—Refitting, Grinding-in bushes, etc. These are taken in hand some time before long holidays so that tradesmen to whom the work is given may be consulted.

Guards.—For the safety of the boys, all gears, switches and dangerous places are fitted with guards and safety devices.

The minimum time for the efficient upkeep of equipment (power driven), and preparation for a class of 16 students is 4 hours weekly.

CONTRACTORS SUPPLYING METALWORK EQUIPMENT AND MATERIALS

"Higg's" Motor, Witton, Birmingham.

"Ingleby" Motors, Holbeck, Leeds.

Messrs. Milnes, Bradford—Lathes and Accessories.

Messrs. Drummond Bros., Guildford, Surrey—Lathes.

Manual Training Tool Co., Sheffield—General Equipment.

Messrs. Tyzack and Sons, Old Street, London—General Equipment.

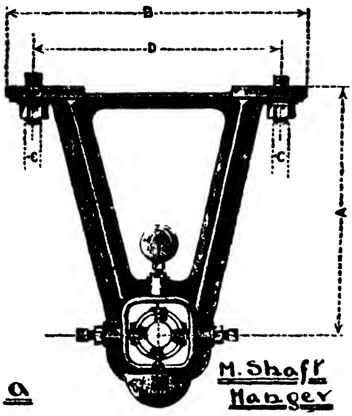
Messrs. Findlay and Sons, Newcastle-on-Tyne—Electro-lathes and Drilling Machines.

T. Senior, Atlas Works, Liversedge, Yorks.—Machines, Accessories, Metal.

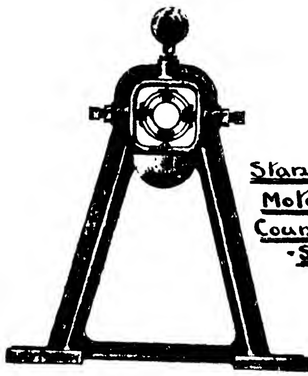
Messrs. Hamilton and Brown, Leeds—Non-ferrous metals.

Messrs. T. W. Young, Ltd.,—Metal Rivets, Solders—City Road, London, E.C.1.

—POWER APPLIANCES—

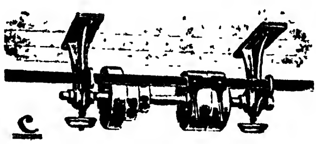


a M. Shaft Hanger



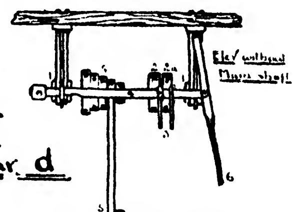
Stand for Motor Counter-Shaft. b

Dimension, Inches—								
A	9	12	9	12	15	18	15	18
B	11	12½	11	12½	19	21	19	21
C	¾	¾	⅝	⅝	⅞	⅞	⅞	¾
D	9	10½	9	10½	16½	18½	16½	18½

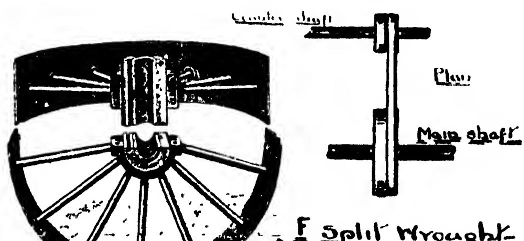


c Lathe Countershaft

Diagram of a lathe drive showing the belt shifting gear. d



e Laminated Wood Pulley



F Split Wrought-Iron Pulley

FIG. 3a.

CHAPTER III.

Mechanics applied to Power Problems.

Some knowledge of mechanics is necessary in order to transmit power from the prime mover, in this case an electric motor, about the room; and also to determine the correct speed-ratio between driver and driven pulleys on shafting and machinery.

On reference to the plan of line shafting, Fig. 2, p. 9, it will be noticed that the main shaft, which is $1\frac{3}{4}''$ in diam., is supported by hangers (A), Fig. 3a, p. 16, and revolves at 140 revs. per minute. This shaft carries all the driving pulleys except those for the two lathes which require countershafts with shifting gear for moving the driving belt from the loose to the fast pulley, and *vice versa*. C and D Fig. 3a show suitable arrangements.

A fast and loose pulley may be fitted on the main shaft for starting and stopping the machinery, but this means bringing the motor and driving belts farther out from the wall. A better arrangement is to have the motor pulley fitted with a centrifugal clutch which allows the motor to take up its load gradually. Two types of split pulleys are shown at (*e*) and (*f*) Fig. 3a, both of which are suitable for small powered plant. No keys are necessary, the frictional resistance of the bushes, when the two halves of the pulley are properly bolted together, being sufficient to prevent its turning on the shaft.

The general arrangement of the line shafting (Fig. 2) may be regarded as a mechanism in which there is a force (the electrical energy of the motor) applied at a fixed point, this force being transmitted for use at other points about the room and in different ways.

The initial force might be called the "effort", and the resistance in the shafting and various machines the "load."

The change of form of the effort may be effected in three ways:—

1. By changing the direction of its application; as in the case of motion being transmitted from the main to counter shafts and thence to machines.
2. By changing a circular motion into a reciprocating or a linear motion; an example of this is seen in a machine hack-saw.
3. By changing the magnitude of the force at a particular point, this being brought about when we use the back gear on a screw-cutting lathe.

It must be made clear that no piece of mechanism will transmit more energy than is put into it. If through the increase in the magnitude of the force, such as is brought about through the leverage of the gears in the last example, when we get an increased turning effort on the lathe mandril, we do this at the expense of time; or, as in the case of overcoming any resistance by a system of levers, then we lose something in the distance through which the force acts.

The power at our disposal is $3\frac{1}{2}$ h.p. and apply it as we will to the best possible advantage we can never increase it. Even with the most up-to-date bearings, careful alignment of shafting, and efficient lubrication, we shall lose some amount of useful work in overcoming frictional resistance.

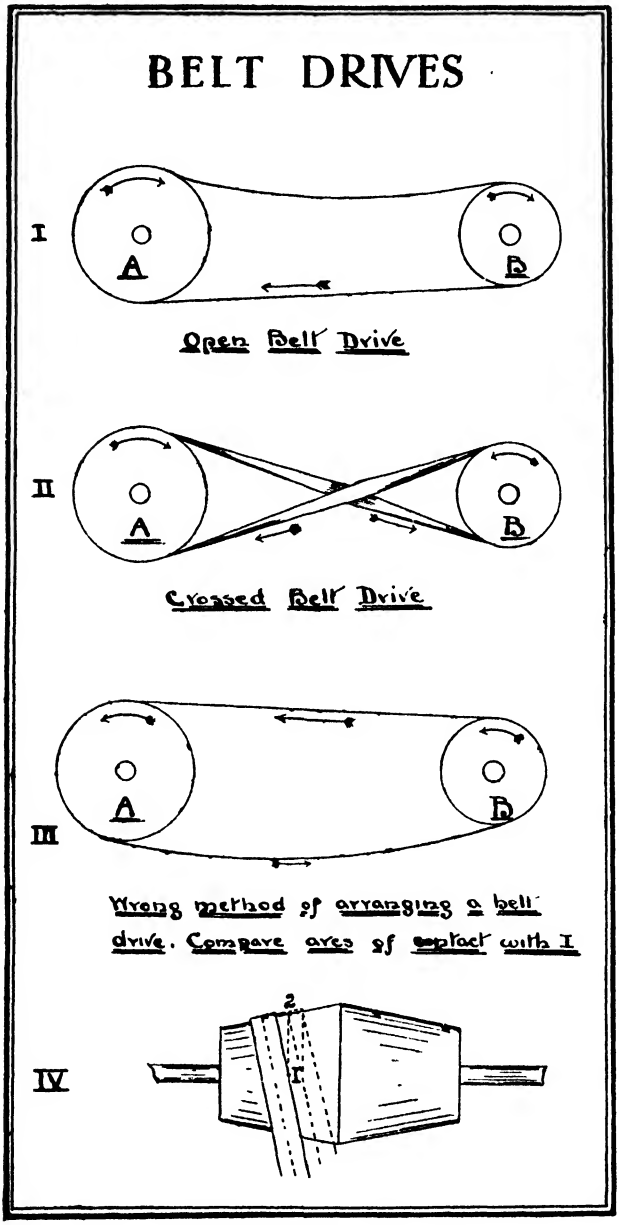

BELT DRIVES
I
A
B
Open Belt Drive
II
A
B
Crossed Belt Drive
III
A
B
Wrong method of arranging a belt drive. Compare arcs of contact with I
IV
2
1

FIG. 3b.

The motor armature spindle, and the small driving pulley fixed on it, revolve at 1,400 revs. per minute but the main shaft is to revolve at 140 revs. in the same time. To bring about this drop with one belt, or in one stage, would necessitate a very large pulley on the main shaft. A better way is to decrease the revolutions in two stages, first by means of a horizontal drive to a medium sized pulley on a countershaft supported at one end by a pedestal (*b*), Fig. 3a, and at the other by a bearing in a wall box, and secondly by a belt drive from a small pulley on the same countershaft to the larger one on the main shaft.

The arrangement is shown in Fig. 2.

The diameters of the pulleys must now be determined.

Fig. 3b (*a*) shows two pulleys connected by an open belt and (*b*) another pair of pulleys of similar diameters connected with a crossed belt. There will be no difference in their relative rates of motion; but if we call 'A' in each case the driver and 'B' the follower, when the driver rotates in a clockwise direction the follower will do the same when the belt is open, but will have a contra-clockwise motion when the belt is crossed.

The wear on a crossed belt is considerably greater than on an open one, but the arc of contact between belt and pulley is increased. When a belt is running at constant speed, say 2,000 feet per min., providing there is no slip, the linear velocity of a point on the circumference of either pulley, or on the surface of the belt, will be the same. But the circumference of the follower 'B' is less than that of the driver 'A' and therefore the number of revolutions per minute will be greater.

The relative speeds of driver and driven pulleys are in the inverse ratio of their diameters.

Thus :—Let D = Diameter of driver pulley.
d = „ „ driven „
N = Revolutions of driver pulley.
n = „ „ driven „

Then if no slipping occurs between the belt and the pulley:

$$D : d :: n : N$$

Therefore $$DN = dn$$

And $$D = \frac{dn}{N} \qquad N = \frac{dn}{D} \qquad d = \frac{DN}{n} \qquad n = \frac{DN}{d}$$

Examples—First reduction of revolutions.

Diameter of pulley on motor spindle. Figs. 1 and 2 = 7″.
Diameter of driven pulley on countershaft = 24″.
Revs. of motor spindle and pulley = 1,400 per minute.
Find Revolutions of driven pulley.

$$D : d :: n : N$$
$$7 : 24 :: x : 1400$$

$$x = \frac{1400 \times 7}{24} = 408 = \text{revs. of countershaft per minute.}$$

Second reduction of revolutions.

Revs. of countershaft = 408

Diam. of driver pulley on countershaft = $6\frac{1}{2}''$.

Revs. of main shaft to be 140.

Find diam. of pulley on the main shaft.

$$\begin{array}{ccccccc} D & : & d & :: & n & : & N \\ 6\frac{1}{2} & : & x & :: & 140 & : & 408 \end{array}$$

$$x = \frac{408 \times 6\frac{1}{2}}{140} = 19'' \text{ Diam. of pulley on main shaft.}$$

Drilling Machine.

Diam. of fast and loose pulleys on the machine = $4\frac{1}{8}''$.

Revolutions required for speed cone on the machine = 360.

Revolutions of main shaft = 140.

Find the diam. of pulley on the main shaft.

$$\begin{array}{ccccccc} D & : & d & :: & n & : & N \\ x & : & 4\frac{1}{8} & :: & 360 & : & 140 \end{array}$$

$$x = \frac{360 \times 4\frac{1}{8}}{140} = 11\frac{1}{2}'' \text{ Diam. of pulley on main shaft.}$$

Hack Saw Machine.—Hacksaws running dry should make 40 to 50 cutting strokes per minute, or one cutting stroke per rev. of the crank disc which is fixed on the same spindle as the driving wheel.

The cutting should be done on the backward stroke for two reasons, viz. :—

1. To ensure the saw blade always being in tension.
2. To prevent lifting of the machine.

To allow of these conditions the driving belt may have to be crossed.

The diameter of the driving pulley on the main shaft is determined as before.

Diameter of follower on the machine = $13\frac{1}{2}''$.

Revolutions of follower on the machine = 80.

Revolutions of main shaft = 140.

$$\begin{array}{ccccccc} D & : & d & :: & n & : & N \\ x & : & 13\frac{1}{2} & :: & 80 & : & 140 \end{array}$$

$$x = \frac{13\frac{1}{2} \times 80}{140} = 7\frac{3}{4}'' \text{ approx.}$$

It is never possible with belt drives to eliminate slip entirely. Even with the best arrangement of belts there is an average loss of from 2% to 3%, and this must be taken into account when calculating the diameters of pulleys. What is known as the "effective diameter" is the diameter of the pulley plus the thickness of the belt.

Vertical belts are a constant source of trouble, owing to the leather stretching through use, or climatic changes, and falling away from the lower pulley. To obtain the best results belts should be arranged to work in a horizontal position having the tight side at the bottom, and running on pulleys well "crowned" on the face. See I. Fig. 3b.

This illustration shows a belt drive arranged horizontally. The driver pulley is turning in a clockwise direction and as the pulleys are connected with an open belt, the follower will have a similar motion. As a belt can only pull, all the work is done by one side called the tight side, the other side running slack. In the illustration the tight side is at the bottom, and the belt running slack on the top, laps over the pulleys and increases the arc of contact. The defect of having the tight side at the top is seen at (III.) the belt falling away from the pulley at the bottom and making the arc of contact less. In order to estimate the power that any belt will transmit we must know the tension in the two parts of the belt, and also the speed at which it is running.

Experiments have been made which prove that the tension in the slack side 'T_2' of a belt is about 0.4 of that in the tight side T_1 when running on iron pulleys.

Let T_1 = pull in lbs. on the tight side.
T_2 = pull in lbs. on the slack side.
d = distance in feet travelled by a point on the belt per minute.

Then considering pulley A. 'T_2' by reason of the sag of the belt is helping it to rotate, and T_1 is retarding it; so, when turning, the driver exerts a nett pull $(T_1 - T_2)$ lbs. to the driven pulley through the medium of the belt.

The amount of work done in one minute will be W foot lbs.

$$\therefore W = (T_1 - T_2) \times d \text{ foot lbs. per minute.}$$

$$\text{and Horse-power transmitted} = \frac{(T_1 - T_2)d}{33.000}$$

$$\text{or taking } T_2 = 0.4T_1$$
$$\text{then } T_1 - T_2 = 0.6T_1$$

$$\text{H.P.} = \frac{0.6T_1 \times d}{33.000}$$

Engineers responsible for the running and upkeep of plant consider that the greatest value of T_1 which can be relied upon is about 80 lbs. per inch of width for a single belt.

Example.—The main driving belt in the first example is 3″ wide and is stressed 60 lbs. per inch of its cross-sectional area in its tight part. Calculate the H.P. it is able to transmit.

$$\text{Speed of belt} = \frac{7 \times 1400}{12} \times \frac{22}{7} = 2{,}500 \text{ feet per min.}$$

$$\therefore \text{H.P.} = \frac{0.6 \times 180 \times 2500}{33.000} = 8 \text{ h.p.}$$

Demonstrating that a belt 3″ wide is ample.

From the foregoing example it will be noticed that the belt speed is 2,500 feet per minute which conforms with good practice.

All pulleys should have their rims turned slightly convex, or " crowned" in order to keep the belt from running off at the sides. The amount of convexity varies but is generally about 1 in 48 for a 12″ face, increasing as the faces become narrower and the speeds higher. For a pulley with a 4″ face and running at a higher speed a rise of 1 in 24 is not excessive.

The reason for this " crowning " of pulleys is made evident if we refer to diagram (IV.) Fig. 3b. A belt 'A' is arranged to run on a conical pulley and the tension in the belt will tend to make it hug the pulley in the manner shown, but a belt always runs to the place where the tension is greatest, therefore the point '1' coming in contact with the pulley will be carried during a portion of a revolution to '2' higher up the pulley face. The belt then assumes the position shown by the dotted lines, and this creeping up the pulley face continues until the belt reaches the crown when it is prevented from being thrown off by putting another half pulley on the other side and giving the faces a slight convexity.

HINTS ON THE ARRANGEMENT AND CARE OF BELT DRIVES.

1. Horizontal, inclined, and long belts give a much better effect than vertical and short belts.
2. Short belts require to be tighter than long ones. A long belt working horizontally increases the grip by its own weight.
3. If there is too great a distance between the pulleys, the weight of the belt will produce a heavy sag, drawing so hard on the shaft as to cause great friction at the bearings, while at the same time the belt will have an unsteady, flapping motion, injurious to itself and to the machinery.
4. Care should be taken to let belts run free and easy, so as to prevent the tearing out of lace holes at the lap ; this also prevents the rapid wear of the metal bearings.
5. It is asserted that the grain side of a belt put next to the pulley will drive 30 per cent. more than the flesh side. Experience alone can verify this, but when the belts are required to be worked this way the fact should be stated in order that the rivetting may be arranged accordingly.
6. If possible, the machinery should be so planned that the direction of the belt motion shall be from the top of the driving to the top of the driven pulley.
7. At least once a term belts should be wiped free from dirt and be given an application of castor oil or curriers' grease. These act as preservatives, and by keeping the belts soft and pliable increase the grip on the pulleys.
8. During vacation, allow belts to hang loose and free.

BOOKS FOR REFERENCE.

Applied Mechanics.—Morley and Inchley. Longmans Green Co.

Applied Mechanics.—D. A. Low. Longmans Green Co.

Engineering Science.—A. G. Robson. Chapman & Hall, Ltd.

Manual of Machine Design.—F. Castle. Macmillan & Co.

CHAPTER IV.

Vise-Work, Chisels and Chiselling.

UNDER the heading of Vise Work is included such operations as chipping, filing, drilling, screwing, tapping, rivetting, braking, and general fitting processes.

The first essential is a good vise, and there are many excellent ones on the market from which to make a selection. A good vise must combine strength with rigidity.

Without rigidity the metal gripped cannot be held firmly, and the whole of the force exerted by the operator when filing or chipping will not be delivered as " work," some of it will be wasted by the spring or resilience in the vise.

Vises are tools of general utility, and serve a wide range of purposes. They are often expected to perform work which is outside their scope, and are very liable to abuse.

It is a common practice, in order to secure a tight grip, to hammer a vise handle or to use a piece of piping to apply greater leverage. How great is the stress set up in the metal and the likelihood of fracture of the cast iron jaws by such methods is seen by the following simple application of Mechanics.

In the vise illustrated in Fig. 4 the screw has four square threads to the inch, and the distance from the centre of rotation to the place where the force of the hand is applied along the handle is 6″. Regarding the vise as a machine—

$$\text{The Velocity Ratio} = \frac{\text{Distance the effort moves.}}{\text{Resulting movement of the load.}}$$

$$= \frac{2\pi \times 6''}{\frac{1}{4}''} = 150.$$

Neglecting friction the force ratio or mechanical advantage would also be

$$\frac{\text{Load}}{\text{Effort}} = \frac{150}{1}$$

or, a force of 10 lbs. exerted at the handle would cause the jaws to grip with a force of 1,500 lbs. In actual practice the frictional losses in vises, screw jacks, and devices of a similar type are very high and the amount of useful " work " done rarely exceeds 50 per cent. of the theoretical amount. But even then, in the case of a vise, excessive leverage on the handle may cause a fracture of jaw casting.

If a tight grip cannot be obtained by an ordinary amount of force on the handle, then the vise has either lost its mechanical efficiency through the want of oiling, or the jaw-plate serrations have worn smooth through long service and require renewal.

For convenience of working vises should be not less than 3′ 6″ centre to centre, and for school purposes the height of the bench to which they are fixed should be 2′ 6″.

VISES.

The parallel or engineers' vise is the one now universally used for bench work. Fig. 4 and 4*a* show vises of this type fitted with a square threaded and buttress threaded spindle respectively for opening and closing the jaws. The two cheeks '*A*' and '*B*' are made of cast iron, the spindle of mild steel, and the jaws, which are renewable, of cast steel. The back cheek '*B*' is bolted down to the bench and, being of saddle form, allows the front piece to slide backwards and forwards through it. The great advantage of this type of vise is the grip afforded over the whole area of the jaw.

In 1884, Joseph Parkinson invented a parallel vise which combined the cramping movement of the ordinary screw vise with a quick and free adjustment of the jaws to any width of opening. Much wasteful expenditure of time and energy is eliminated by this device which may be said to have had a revolutionary effect on the vise-making industry. Fig. 8*a* illustrates the interior of a Parkinson's "Perfect" vise, fitted with a quick-action movement. The screw spindle 'K' has a buttress thread, which engages with a similar thread on a half nut '*S*' for the screw action when gripping. The half nut has a shank projecting from its underside with a groove cut across its lower end in which a rocking bar '*D*' engages to move the nut up and down when in working position. When it is desired to slide the jaw '*A*' quicker than by the screw, the screw knob '*H*' and lever '*C*' are gripped together. This turns the bar '*D*' and withdraws the half nut clear of the screw. The jaw '*A*' can now be pushed forward or pulled backward to any required distance within the limits of the vise-opening. When the lever 'C' is released the spring '*I*' causes the bar '*D*' to resume its initial position and in doing so it lifts the half nut into mesh with the screw. Fig. 8*a*.

SPECIFICATION FOR VISES
SUITABLE FOR USE IN A METAL WORKROOM.

Engineers' Vises, Parkinson "Handy" type, $4\frac{1}{2}''$ width of jaw, opening 5″, weight about 45 lbs. :—

Two vises 4″ width of jaws fitted with quick-action movement.

The jaws to have interchangeable face blocks. One pair of such blocks to be supplied.

Each vise handle to be fitted with a rubber band at each end secured with a metal fastening to lessen noise when handle is dropped.

On reference to Fig. 1 it will be observed that in addition to the parallel vises, a leg vise has been included. For filing and general bench work the parallel vise, owing to its more effective grip and convenience of handling, has superseded this old-fashioned type, but, being forged instead of cast, a leg vise is stronger and more likely to withstand heavy usage. Fitted near the forges one will be found convenient for holding work during hammering, bending, chipping, twisting, etc.

By reason of its construction the leg vise has one serious disadvantage. The loose jaw being hinged at the bottom end always moves in the arc of a circle. This means that the jaws never grip over the whole of their face area, and it is difficult to fix work with truth and squareness between them.

PARALLEL VISES

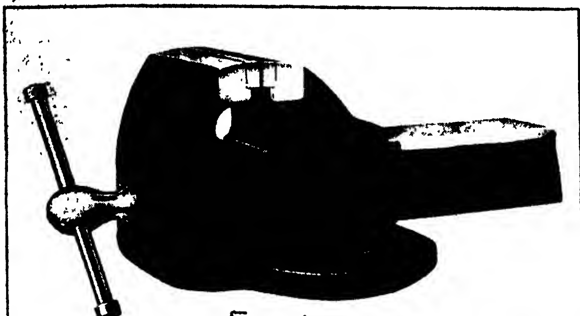


Fig. 4.

Leg Vise
Wrought Iron Body
Mild Steel Screw
Steel Faced Jaws
Height 3'–1"
Jaw Width 4½"

Fig. 4a.

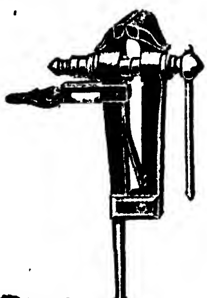
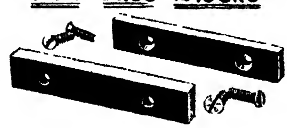


Fig. 5.

Fig. 6

Portable Vise Stand.
Height of Table 30"
Top " " 19"x 18"

Jaw Face Blocks



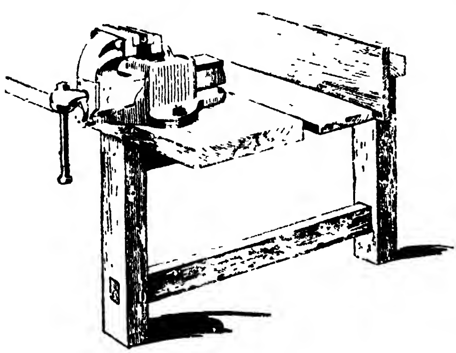


Fig. 7.

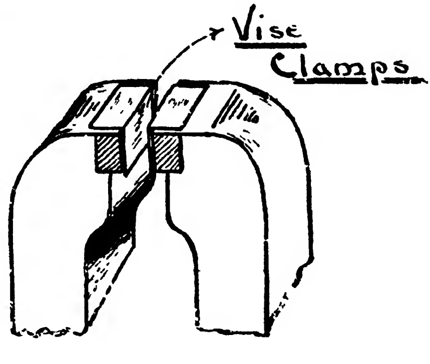
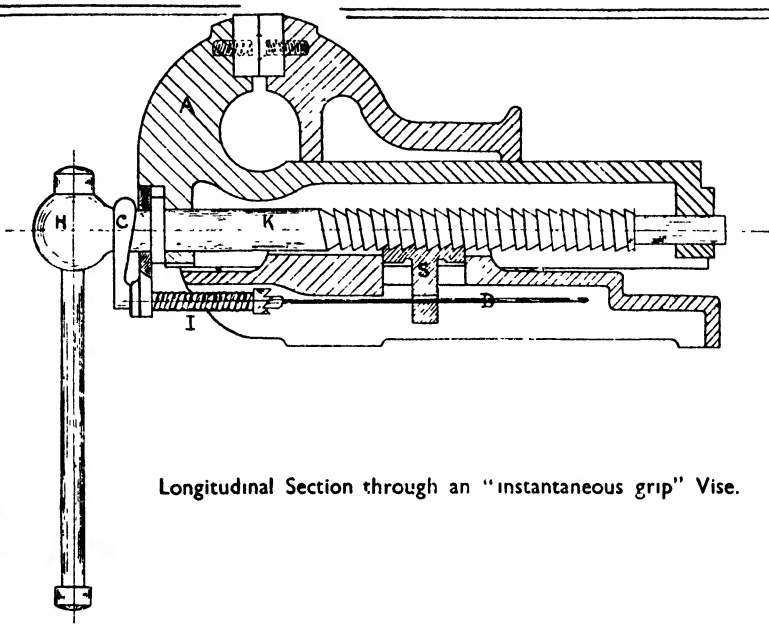
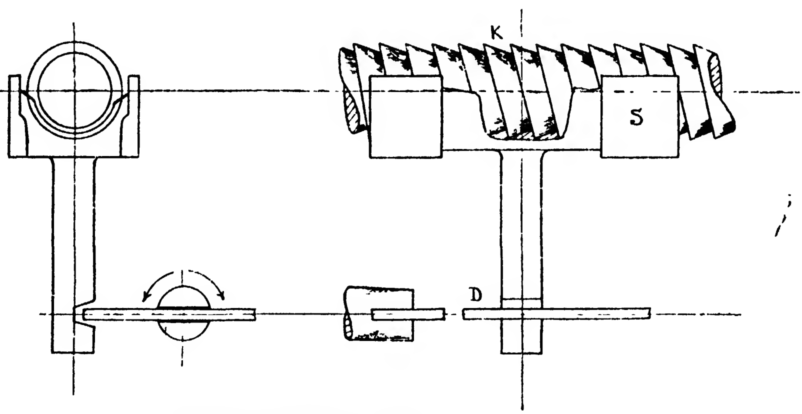


Fig 8

VISE DETAILS.



Longitudinal Section through an "instantaneous grip" Vise.



Details of Screw and Nut.

Fig. 8a.

To secure rigidity in a vise, it must be mounted in the best position on the bench. This as shown in Fig. 7 is immediately over a leg of the framing.

Before any work which has to be well finished is gripped in a vise it should be placed between pieces of sheet metal, preferably copper, gauge 12 or 14. Spare pieces of tinplate will do, but they require frequent renewal. Such pieces are bent to the shape of the jaw, Fig. 8, and are called clamps or " clams." They prevent the serrations of the jaws biting into the metal being worked. Care should be taken to see the clamps are slightly narrower than the width of the jaws; if sharp corners are allowed to overhang, accidents such as torn fingers are likely to be the result.

FILES.

FILES are the commonest tools used by the metal worker. They fulfil the same purpose as the plane does for the craftsman in wood. Every piece of fitted work involves some filing, and it is necessary that the difficult operation of handling a file in a business-like manner should be thoroughly taught and learnt.

The cuts given to files are named as follows: –

Rough	cut	14	to	22	teeth	per	inch.
Middle	„	16	to	26	„	„	„
Bastard	„	22	to	32	„	„	„
Second	„	28	to	42	„	„	„
Smooth	„	50	to	65	„	„	„
Dead	„	70	to	110	„	„	„

Whilst all these cuts are used in engineering practice, experience has shown that for handicraft purposes the bastard and smooth cut are the most serviceable. Each student should be provided with a 10″ parallel file in each of these cuts. If drawers are fitted underneath the vise bench top and provided with racks, one can be used to store coarse files, another smooth, another assorted, and so on. This method will be found to be more convenient than having small racks opposite each vise; and, further, it permits of rapid supervision.

In addition to the files above mentioned, it will be necessary to have an assortment in different lengths of half-round, round, square, cotter, and three-square files.

FILING.

When commencing filing, it should be arranged that the work to be filed should be level with the worker's elbow. Most beginners use a file with a rocking motion, and to prevent this the file must be held as shown in Fig. 9.

The handle of the file is resting in the palm of the hand with the thumb upward. The other end may be gripped with the left hand and some pressure put on for a heavy cut, or held between the finger and thumb for a light one. Since a file cuts on the forward stroke only, any pressure that is put on it is released on the backward or return stroke.

"PINNING."

Particles of the material being cut sometimes become embedded in the teeth of the file and make scratches on the surface of the work. This is particularly noticeable when filing copper, and is known as " pinning." When it occurs, the file must be cleaned with a wire brush or " file card." Rubbing the file with chalk before using also prevents pinning, but used carelessly makes a mess of floor and bench.

FIG. 9.—CORRECT POSITION FOR FILING.

DRAW-FILING.

The object of draw-filing is to give finish to work which has been trued-up or brought to shape by coarser cut files. The smooth or dead-smooth file is held by the finger tips and thumbs only, and is carefully pushed and drawn sideways over the work. The scratches left by coarser files are obliterated in this way and the appearance of the work is considerably improved. Small tools, like dowel plates, calipers, engineers' try-squares, are all draw-filed before being further finished with emery cloth and oil.

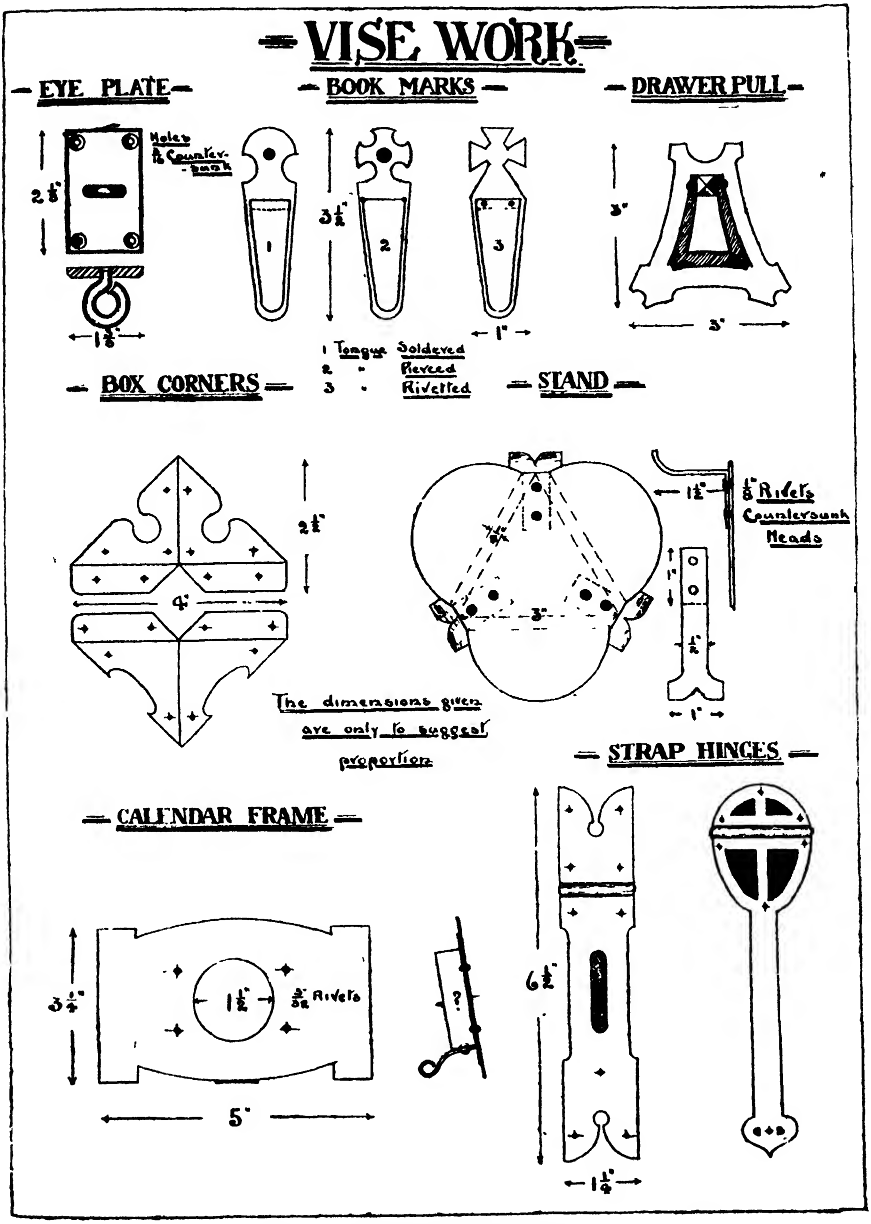


FIG. 10.—ELEMENTARY PROJECTS.

ELEMENTARY PROJECTS.

Several suggestions are given in Fig. 10, which are suitable for students commencing vise-work. It will be observed that filing is only necessary on the edges of the metal. Broad flat surfaces are to be avoided, until the student is familiar with the use of the file. Recollections of the laborious effort put into the filing of cubes, hexagonal prisms, etc., in the early days of metal-work practice in schools are still vivid in the minds of some former pupils, as well as the failures which resulted. It is safe to say that with the present-day use of machinery such exercises would tax the skill and ingenuity of a great number of mechanics were they to attempt them with hand tools now.

(1) Eye Plate.—Made from mild steel $1\frac{1}{2}'' \times \frac{3}{16}''$. The eye is forged from $\frac{1}{4}''$ diameter wrought iron and rivetted in. When completed the plate can be kept until a gate-hook is forged at a later period and then attached to it.

(2) Book Markers.—Made from No. 20 gauge sheet brass. The tongue may be either soldered on as at '*A*,' drilled and cut with a jeweller's piercing saw, as at '*B*,' or rivetted on, '*C*.'

(3) Drawer Pull.—Back designed to suit some particular job. The drop piece in the centre is drilled and filed to shape; then it is fixed with a pin joint to the projecting piece '*A*,' which is rivetted through the back.

(4) Box Corners.—Material No. 18 or 20 sheet brass. Designed and developed as shown. Drilling should be done before bending. For the bending, which must be done very accurately to complete a neat square job, folding bars are used.

(5) Stand.—Material No. 16 gauge sheet iron. Mark out the top, centre punch along the outline, cut out with chisels and finish with files. Prepare the legs from one piece of metal. Drill the holes and rivet on the legs whilst they are straight. Bend at right angles in the vise, and finally curve out the feet on a mandril.

(6) Calendar Frame.—Material No. 16 sheet iron. Make suitable designs, limiting the size of the front to say $5\frac{1}{2}'' \times 3''$; cut out and finish. Develop and fold the back pocket and rivet to the front. Design and make a suitable support to complete the project.

CHISELS AND CHISELLING.

Some opportunity should be given to the metalwork student to become familiar with the use of chisels, and gain experience in chiselling operations.

In the fitting shop a great deal of work that was formerly "chipped" and cut with chisels is now machined, but there are many occasions, both in school and workshop, where ability to use a hand tool skilfully, is necessary for the satisfactory completion of a job.

In the metalwork room the chief operations demanding the use of the chisel are:—

I. Cutting out thick sheet metal on blocks, or, the removal of waste when the work is held in a vise.

II. Chipping the skin of a casting to prevent injury to files and cutting tools.

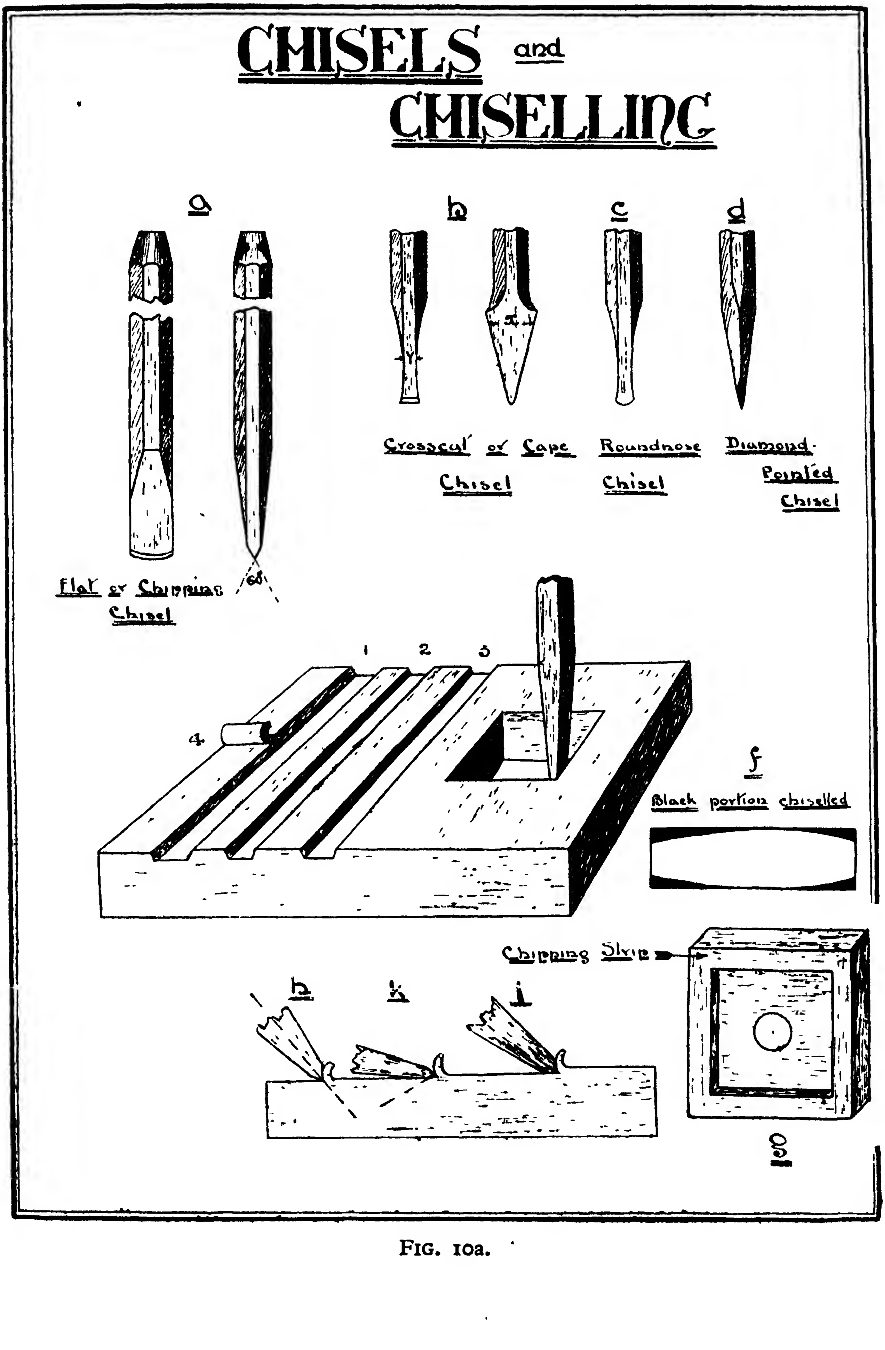

CHISELS and
CHISELLING
a
b
c
d
Crosscut or Cape
Chisel
Roundnose
Chisel
Diamond
Pointed
Chisel
Flat or Chipping
Chisel
1
2
3
4
f
Black portion chiselled
Chipping Strip
h
k
i
g

FIG. 10a.

III. Removal of waste materials to save time and much laborious filing. Fig. 10a.

IV. The cutting of keyways and grooves, and the "drawing over" of centres (see chapter on drilling).

The forms in which chisels are made are shown in Fig. 10a. The cutting angles are ground to an angle of approximately 60°, but, as in the case of wood-cutting chisels, this angle is an arbitrary one, some materials permitting of a more, and others a less degree of acuteness for efficiency in use. The flat or chipping chisel (*a*) has its cutting edge ground slightly convex to prevent the corners from "digging in." In no case should it be "hollowing" in its use, because this weakens, and renders the corners liable to be broken off. Two of the uses of this tool are suggested at (*f*) and (*g*) Fig. 10a. The poker end shown at (*f*) has to be shaped from a piece of $\frac{5}{8}''$ square mild steel, and after the shape has been scribed round a template on the metal, the black portion is chipped away, files being used afterwards to finish to size. The square base piece (*g*) is a casting, the surface of which should be chipped to remove the "skin" before filing. The underside is recessed in the moulding, leaving an outside rim. This is called a "chipping strip," and by its use only a comparatively small area of metal has to be chipped and filed in order to secure good bedding and rigidity.

The crosscut chisel (*b*) is made wide at '*x*' to compensate for the narrowness at '*y*' and give it the necessary strength. In order to give clearance, and facilitate the progress of the tool along a groove, the cutting edge should be slightly wider than the body.

For cutting out small curves, and for making circular grooves, the round nosed chisel (*c*) is employed. If of large size for cutting out sweeps, and shaped like a gouge, the term "cow mouthed" is applied to it.

The chief uses of the diamond pointed chisel (*d*) are for the trimming of square internal corners, and the drawing over of centres in drilling practice. This tool being very liable to break with heavy usage, the bevelled or diamond face should not be ground too acute, an angle of from 30° to 40° being sufficient.

The cuts made by these chisels are illustrated at (*e*) which represents a casting with a cored hole through it. To reduce the thickness for a portion of its length, a line should be drawn and centre-punched to denote how much material has to be removed. The grooves 1, 2 and 3 would then be cut with a crosscut chisel, care being taken not to cut right through from one side, and so avoid breaking off the back corner.

The chipping chisel would then be employed to remove the metal between the grooves, and a tolerably flat surface prepared for filing. A cut, partly completed, is shown at '4,' Fig. 10a. Preparatory grooving is always necessary, when chipping wide surfaces, to prevent the corners of wide chisels from breaking, and, in addition the grooves serve to weaken considerably the intervening metal and facilitate the chipping. To chip smoothly, the facets forming the cutting edge of the chisel must be ground flat. The slightest roundness or hump will cause the tool to rise out of the cut and the surface of the work to be uneven. The facet meeting the surface requires to be held in the exact plane along which the cut is to be carried. For example, Fig. 10a (*h*) shows a chisel held so that the bottom facet forms an acute angle to the surface of the

work. The force of the blow being in the direction of the dotted line, and the shaving offering resistance to the chisel, its cutting edge digs into the metal. Supposing, on the other hand (*k*) is a chisel held at the inclination shown, its bottom facet forming an obtuse angle to the intended line of cut, then, the metal beneath that bottom facet, indicated by the dotted line, forms an inclined plane up which the chisel naturally moves at each blow. But, if the plane of the bottom facet is coincident with the line of the cut, as at (*l*), it acts as a guide to steady the chisel, and to prevent it from cutting too deeply; there being no tendency for the tool to lift, it will move forward in a straight line, producing even work.

The chisel should be held so that its head does not protrude more than half an inch above the hand or fingers, since the nearer to the head it is grasped the steadier it can be held. The chisel should always be grasped firmly, and pressed into the cut with a firm and steady pressure.

Many fitters frequently lubricate the cutting edge by rubbing it on a pad of oily felt, but it is doubtful whether this serves any useful purpose beyond cooling a thin edge that has been hard driven, thereby preserving its temper.

CHAPTER V.

Drilling and Drilling Appliances.

DRILLING.

HOLES must be made in metal for a variety of reasons :—

(*a*) roughly for the quick removal of material and to facilitate the entry of other tools, chisels, hack saws, files, etc. ;

(*b*) accurately for the admittance of rivets, bolts, studs, etc., and preparatory to screwing with taps ;

(*c*) very accurately in the fitting of links, and where diameters have to be within definite limits. The cutting tools used are called drills, of which there are many kinds, each having its own particular use. The operation of drilling may be performed either with hand appliances, drilling machine, or in a lathe.

DRILLS.

The flat pointed drill used to be by far the commonest type, but this can hardly be true to-day, because the use of Morse twist drills has become universal. The ease with which the flat drill can be made and tempered to any degree of hardness constitutes its chief advantage.

'*A*' Fig. 11, shows the round shank forged out to a flat blade with a short parallel end. The bottom edge is ground diamond shape, the two sides being equally inclined to an angle of about 40° to the horizontal. The edges thus formed are the cutting edges and are bevelled back to give a small "angle of relief." This angle varies between 3 and 10 degrees, a drill for iron and steel having less clearance than one for copper, aluminium, or brass.

With a straight flat blade no front rake can be given to the edges, and when the blade is made thinner at the point than higher up, as at (*a*), the rake becomes negative. This and other defects make the flat drill the most defective of all cutting tools as regards the relation of driving power to the amount of material removed. The defect increases in magnitude the larger the ratio of the thickness of the blade to the diameter of the hole, and it is consequently greater in drills for small holes, because it is practically impossible, without weakening the drill, to reduce the thickness of the blade in proportion to its width.

When once drilling has commenced the only guidance that can be given to the tool is afforded by the bearing of the cutting edges and parallel sides of the drill against the material. In the case of the flat drill this bearing is small, and should the metal be irregular in texture or have internal "blow holes" the cutting edge will "run" from the hardest material and make a hole "out of truth." This fault is termed "wobbling," and is more likely to occur with cast than with rolled or forged metals.

ADVANTAGES OF FLAT DRILLS.

1. Easily and cheaply made for any special purpose.
2. Will withstand heavy usage without materially damaging the cutting edges.
3. Tempered quickly in a smith's fire for material of varying degrees of hardness.
4. For shallow holes in brass a flat drill or a fluted drill is to be preferred to a twist drill.

DISADVANTAGES.

1. Lack of guiding surface for drilling deep holes.
2. Must be frequently withdrawn to clear the cuttings.
3. Does not cut in the true sense, but scrapes.

TWIST DRILLS.

To Manchester and Leeds belongs the credit for the invention of the twist drill. Both the late Sir Joseph Whitworth and Mr. Greenwood experimented with drills of this type as far back as 1850 but without any great success. The pitch of the spiral of the grooves was too small and caused the cutting edges to dig in, and, being made of a much inferior material than that used to-day, to fracture. It was left for an American engineer, Mr. Henry Morse, to remedy the defect and perfect the Morse Twist Drill which furnishes another instance of an invention revolutionising an industrial process.

Initial cost may seem heavy compared with that of flat drills, but greatly increased output, together with cutting efficiency, soon compensates for the additional outlay.

On examining the sketch at (*b*) Fig. 11, or better still, a large diameter Morse drill itself, it will be seen that the great fault of the flat drill, viz., lack of front rake, is overcome. The inclination of the spiral to the axis is the front rake of the tool, and as the tool point is re-ground farther and farther back the cutting faces are always at the same inclination.

Twist drills are said to be parallel throughout their length, but this is not strictly correct, there being a very slight taper from the cutting to the shank end. Beyond affording a slight body clearance this is of no consequence in actual practice, and the long " parallel " sides guide the tool when boring deep holes.

On examination of a large section of a twist drill (*c*) Fig. 11, the material is found to be " backed off " just behind the cutting edge of the spiral so as to reduce the friction of the sides of the drill upon the hole and give the drill as much body clearance as possible.

Another excellent feature is the clearance afforded for the cuttings which are forced up the grooves of the spiral, leaving the hole clear of the metal cut away and so lessening the frictional resistance to the tool. Again looking at the end of the drill (*c*) Fig. 11, a small flat edge between the cutting faces will be seen. This edge scrapes out the core of the hole in a similar manner to the flat drill. In this respect the Morse drill is worse than the flat, because the length of this cross edge is slightly increased and consequently the central core is left larger.

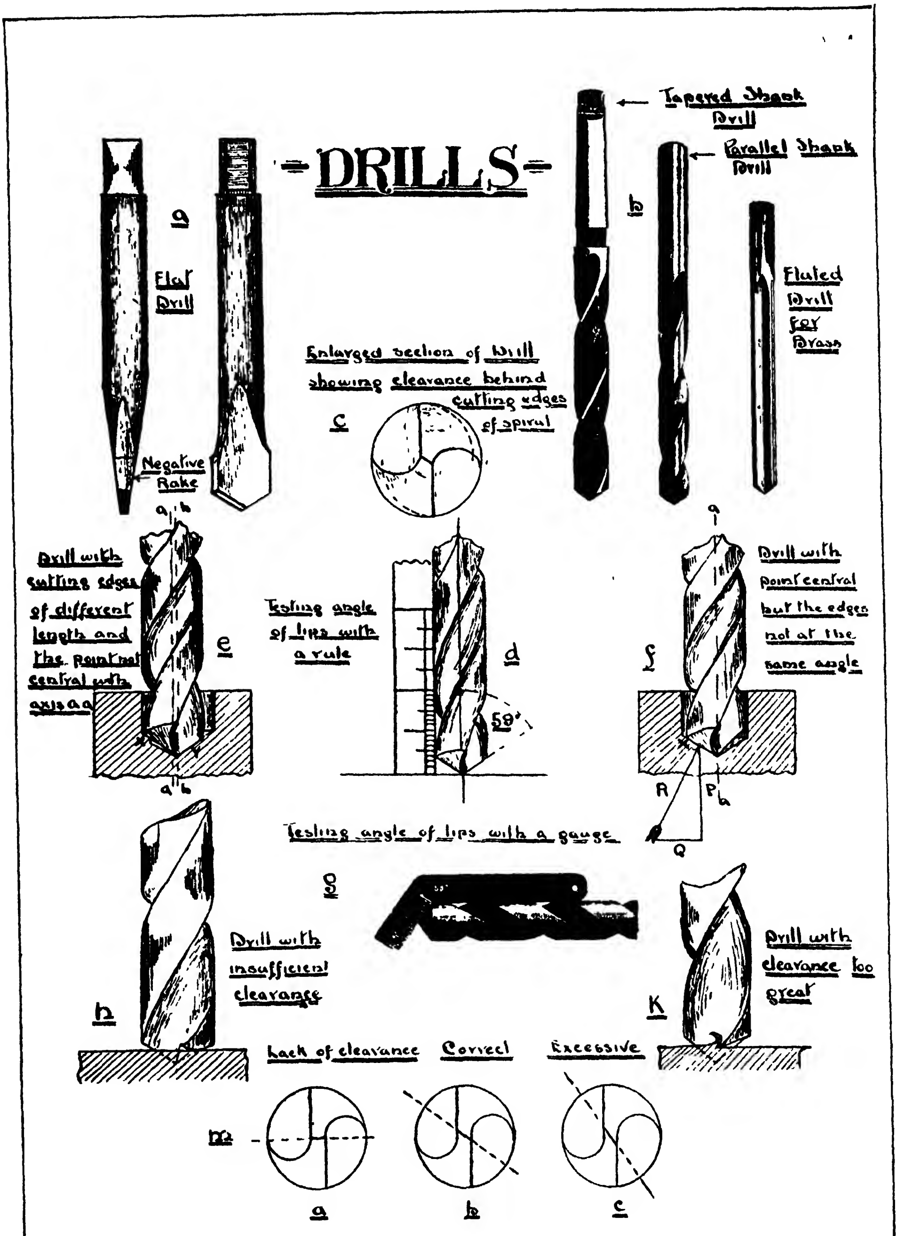

DRILLS
Tapered Shank Drill
Parallel Shank Drill
a
b
Flat Drill
Fluted Drill for Brass
Negative Rake
Enlarged section of Drill showing clearance behind cutting edges of spiral
c
Drill with cutting edges of different length and the point not central with axis a a
e
Testing angle of lips with a rule
d
59°
f
Drill with point central but the edges not at the same angle
R
P
Q
Testing angle of lips with a gauge
g
Drill with insufficient clearance
h
Drill with clearance too great
K
Lack of clearance
Correct
Excessive
m
a
b
c

FIG. 11.

ADVANTAGES OF TWIST DRILLS.

1. Rapid in cutting because mechanically correct in design.
2. Self clearing. No power lost in overcoming the frictional resistance of the cuttings.
3. Long parallel sides afford guidance and prevent drill from "wobbling."

DISADVANTAGES.

1. Costs may be heavy if drills are carelessly used and breakages are frequent.
2. The angles of the faces and lips are soon altered, and grinding is a delicate process.
3. If the temper is once "drawn" through overheating, re-tempering without special facilities is never satisfactory. For school purposes the drill may be considered worthless.

GRINDING.

For convenience in grinding many twist drills have a centre line marked on them as at (*d*) Fig. 11, and the cutting edges are ground at an angle of 59° to this line. Better results will be obtained in drilling brass if the angle is reduced to 50°, the drill being made more pointed. The lip clearance varies with the grinding, but in new drills direct from the makers, is usually 5°.

The operation of grinding a twist drill accurately by hand calls for a considerable amount of skill, the following essentials having to be borne in mind :—

1. The point must be central.
2. The lips must be of equal length and equally inclined.
3. The necessary amount of clearance must be given behind the cutting edge.

The centre line down the drill makes it a comparatively easy matter to keep the point central enough for ordinary work, but the grinding of the lips is a more difficult matter.

THE EFFECTS OF BAD GRINDING are shown in Fig. 11, at (*e*), the cutting edge *x* is longer than *y* and the point is not central with the drill axis *aa*. The pressure on the head of a drill ground in such a manner would force the point to become the axis of revolution and the tool would turn on the line *bb* thereby producing a hole of larger diameter than itself. Both cutting edges would operate, the lower edge of *y* making a hole which the top corner of *x* would enlarge.

(*f*) Shows what would happen if a twist drill were ground with its point central to its axis *aa*, but with the cutting edges not at the same angle. Again the hole would have a larger diameter than that of the drill because of the reaction on the cutting edge *x* to crowd or push the drill over to the opposite side of the hole. This is demonstrated graphically in the same illustration. The reaction represented by the vector '*R*' is resolved into its two components '*P*' and '*Q*.' The horizontal component indicated by the vector '*Q*' shows the magnitude of the force tending to push the drill over from the vertical and thereby enlarging the hole. Cutting is only being performed by the one edge *x*, causing it to become dull more rapidly than it should.

The importance of correct lip angle is apparent when we consider that a twist drill only penetrates the material about 1/100 of an inch per revolution—this is known as the feed—each lip when properly cutting removing an equal amount of material. If one lip is more prominent than the other to the extent of 1/100 of an inch, it follows that the whole of the material removed during each revolution will be cut away by the one cutting edge, with the result that its cutting power will be quickly diminished even if it withstands the stress put upon it and does not break down altogether.

CLEARANCE.

When drills have been ground by hand they may be tested for correct lip angle by standing the drill vertically on a plate and applying an engineer's rule (*d*) Fig. 11, or a gauge may be used as shown at (*g*) in the same figure. Both these methods will check the length of the cutting edges, but there is difficulty in applying them to small drills and they form no guide in grinding the clearance at the back of the cutting edge. This must be judged entirely by appearance. If insufficient clearance is given, the drill will not cut, as the cutting edges cannot reach the metal, see (*h*) Fig. 11, while if pressure is put on the head either by hand or self-acting feed, the tool is likely to be broken.

On the other hand if the clearance is excessive, as at (*k*), the edges are likely to dig in and break, or, in the case of a belt driven machine, " pull up " the machine and throw off the belt. (*m*) Fig. 11 gives diagrams of how the clearance may be judged when the cutting end of a twist drill is examined.

If, after grinding, the small edge *e* is at right angles to the cutting edges as at '*A*,' there is no clearance and the drill will only scrape.

'*B*' shows a drill with the correct amount of clearance ready to perform good work, and '*C*' one with an excessive amount, the tendency being for the cutting edges to become embedded in the metal.

From the foregoing remarks it would appear to be almost impossible to grind a twist drill by hand to do really efficient duty. This has long been recognised in engineering practice, and the system adopted in fitting shops is to issue drills from a tool-room, where they are ground in a twist drill grinding machine. Should the drill be found defective, or become dull, the workman returns it and receives another, no grinding by hand being allowed.

TEST FOR ACCURATE GRINDING.

A drill ground in a grinding machine should remain stationary at any point when held vertically in a hole which has been drilled by it, and where opportunity presents itself this forms an interesting experiment to show the superiority of modern machine, over hand methods in workshop practice.

DRILLING APPLIANCES.

For small holes a hand drill, Fig. 12, may be used on the softer metals, and one or two hand drills in the metalwork room will be very useful.

YANKEE DRILL.

'*A*' shows an improved type of Archimedean drill. It is so constructed that the drill runs continuously to the right during both the forward and backward movement of the driver. The head is provided with ball bearings to reduce friction, and the chuck will hold any drill shank up to $\frac{3}{16}''$ diameter.

— DRILLING APPLIANCES —

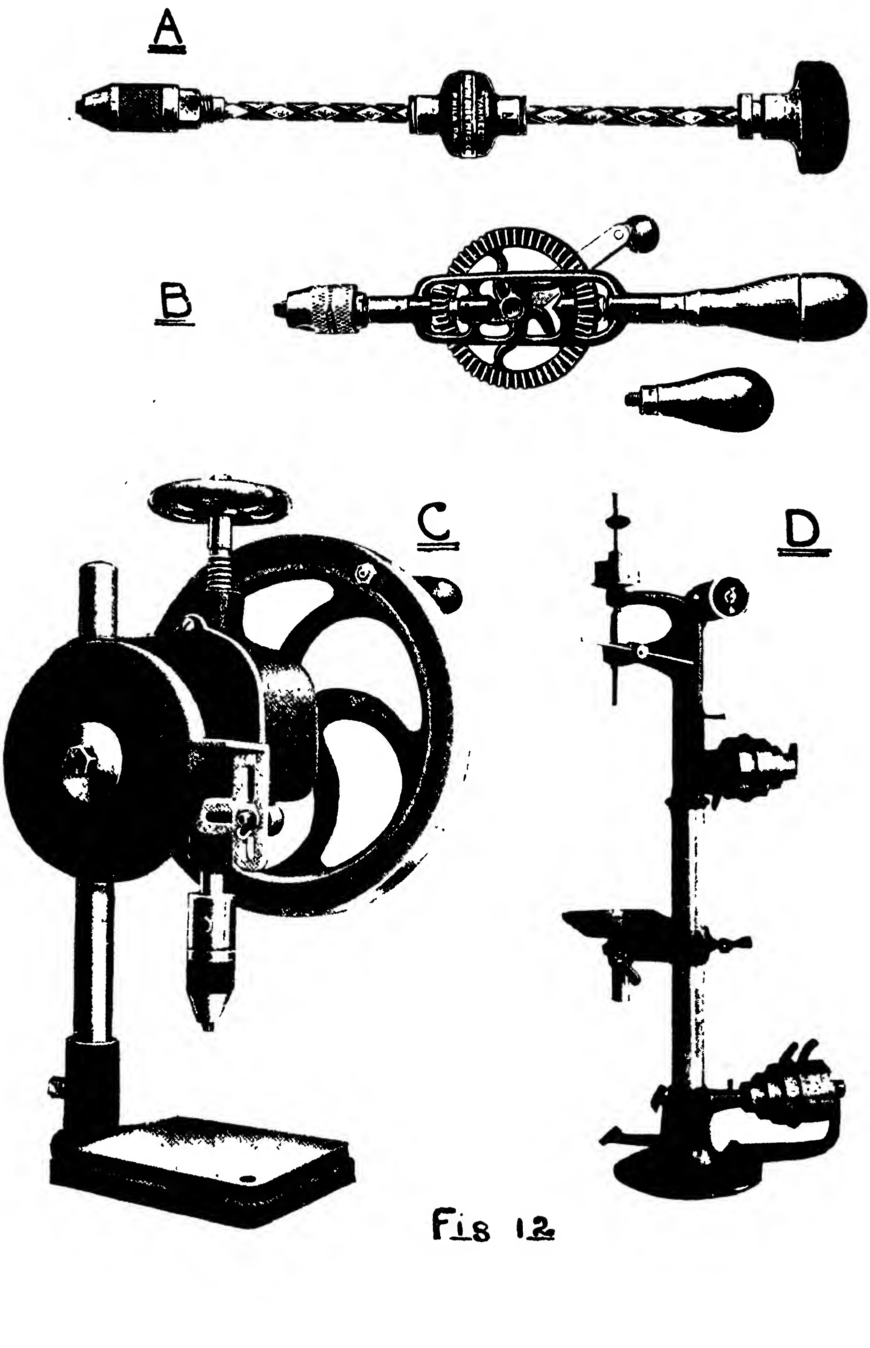


Fig 12

BENCH DRILLS.

There are many types of bench and wall drilling machines which are suitable for equipments both with and without power. It is rarely necessary to drill holes larger than $\frac{5}{8}''$ diameter in the work under discussion, and this should be borne in mind when ordering. '*C*' shows a bench drill with a new idea of a combined drill and tool grinder. The gears are enclosed to prevent the access of grit. The specification for such a machine suitable for a school metalwork room is as follows :—

SPECIFICATION.

Drills Holes up to.	Drills centre of.	Depth of Feed.	Spindle to Table.	Total Weight.	Extra F. & L. Pulleys.	New Grinding Wheels.
$\frac{5}{8}$ in.	8 in.	$2\frac{1}{2}$ in.	$9\frac{1}{2}$ in.	56 lbs.	10/-	10/-

POWER DRILLING MACHINES.

Of power drills one of the sensitive type shown, '*D*,' to drill holes up to $\frac{5}{8}''$ diameter will be found the most convenient for general all round work. There are many varieties on the market, each having its own peculiar features of design, but all have the common feature of the drill spindle being sensitive to hand pressure when applied to the lever (H) Fig. 13.

The spindle is made to rotate by means of the pulley which is fitted on the inside with a feather key. This key slides easily along the groove in the spindle and allows of the drill being either raised or lowered whilst rotating.

Feed is imparted to the drill by turning the handle '*H*' in a contra-clockwise direction. A pinion engages with the rack on the sleeve '*S*' causing it to slide in the lower bearing. The spindle revolves inside the sleeve, the latter being prevented from rotating by the usual groove and "feather" arrangement. A spring in the box '*B*' raises the spindle back to its original position when pressure on the handle is released.

Instead of feather keys, set screws with the ends filed to fit the grooves and case-hardened, are frequently used in light machines.

The sleeve '*S*' is graduated to read $\frac{1}{16}$ of an inch and is fitted with a stop for drilling holes to an exact depth.

The table rises and falls and is counterpoised by a weight concealed inside the hollow vertical column. A vertical line is marked down the centre of the column, and there is a corresponding mark on the table bracket. When these are co-incident, the centre of the hole in the table, made to carry a dead centre, and the centre point of a drill in the machine are in correct alignment.

In the machine illustrated the countershaft is on the floor level. For starting and stopping, the foot lever is rocked over with the left foot, leaving the hands free for feeding the drill and operating the work.

CHUCKS.

The bottom end of the spindle is hollow and provided with a Morse taper, and large drills, the shanks of which have a corresponding taper (*b*) (Fig. 11) can be used in the spindle without a chuck. But with parallel drills a chuck of some kind must be used. It is advisable to use two, one for drills up to a $\frac{1}{4}''$ and one for drills above that size. . The smaller one may be operated by hand, the three jaws opening or closing automatically. The section shown

at (*a*) (Fig. 14) is of a drill chuck of this type, whilst (*b*) shows a larger chuck the jaws of which engage with a plate spiral which moves them to or from a centre. This chuck is also operated by hand, but many of the same type require a key for tightening up and releasing the drill.

DRILLING PROCESSES.

CUTTING SPEEDS OF DRILLS.—The peripheral speed of drills is expressed in feet per minute, that is the rate at which the cutting edge of the tool is moving, or :—

$$\begin{aligned}\text{The Cutting Speed} &= \text{Length of material cut per minute.}\\ &= \text{circumference of drill} \times \text{revolutions per minute.}\\ &= \frac{\pi d}{12} \times n\end{aligned}$$

and taking the revs. per minute of a $\frac{1}{4}''$ drill made from carbon steel as 340.

$$\text{For } \tfrac{1}{4}'' \text{ drill Speed} = \frac{22}{7} \times \frac{1}{4} \times \frac{340}{12} = 23 \text{ feet}$$

For wrought iron this conforms with good practice.

The following table gives the approximate speeds and feeds for carbon steel twist drills for drilling the same material. When all conditions are favourable, the drill in first class condition, the machine spindle perfectly true, and the metal mild and uniform in texture, higher speeds may be used.

CUTTING SPEEDS AND FEEDS.

Diam.	Revs. per min.	Revs. per inch feed.
$\frac{1}{8}''$	660	200
$\frac{3}{16}''$	480	200
$\frac{1}{4}''$	340	150
$\frac{5}{16}''$	280	120
$\frac{3}{8}''$	240	100
$\frac{1}{2}''$	160	100
$\frac{5}{8}''$	140	100
$\frac{3}{4}''$	115	100
$1''$	75	100
$1\frac{1}{2}''$	55	100

The speeds for drilling brass, copper, zinc, may be 100 per cent. greater than those given in the table, but it will be found advisable when working with cast iron to reduce these slightly.

The introduction of high speed steel for cutting tools makes it possible to drill at very high speeds without damage being done to the drill. Messrs. Armstrong Whitworth use a high speed steel for drills which allows a $\frac{1}{4}''$ diameter drill to be driven at 1,400 revs. per minute. Compare this with the speeds for ordinary drills given in the Table.

If a graph were drawn from the data given, the curve would show that the peripheral speed is not constant, but is higher for drills with small diameters. The reason for this is that the heat generated during cutting is absorbed very quickly by small drills. Large drills have a larger surface for absorbing this heat, but it must be remembered there is a much greater

amount of material removed. The surfaces of cylinders are proportional to their diameters, so, comparing the work done by two drills say $\frac{1}{8}''$ and $1\frac{1}{2}''$, the $\frac{1}{8}''$ drill has $^1/_{12}$ the surface area of the $1\frac{1}{2}''$ drill. But the circular area of the cuttings removed varies as the squares of the diameters.

Therefore

$$\frac{\text{Area cut}}{\text{from } \frac{1}{8}'' \text{ drill}} : \frac{\text{Area cut}}{\text{from } 1\frac{1}{2}'' \text{ drill}} :: (\tfrac{1}{8})^2 : (1\tfrac{1}{2})^2$$

$$\textit{i.e.}, \ ^1/_{64} : 2\tfrac{1}{4}$$

$$\textit{i.e.}, \ 1 : 144$$

That is, whilst the small drill has only $^1/_{12}$ the surface of the larger for absorbing frictional heat, the amount of material removed per revolution is only $^1/_{144}$. We see therefore that small drills can be driven at much higher speeds than those of large diameter.

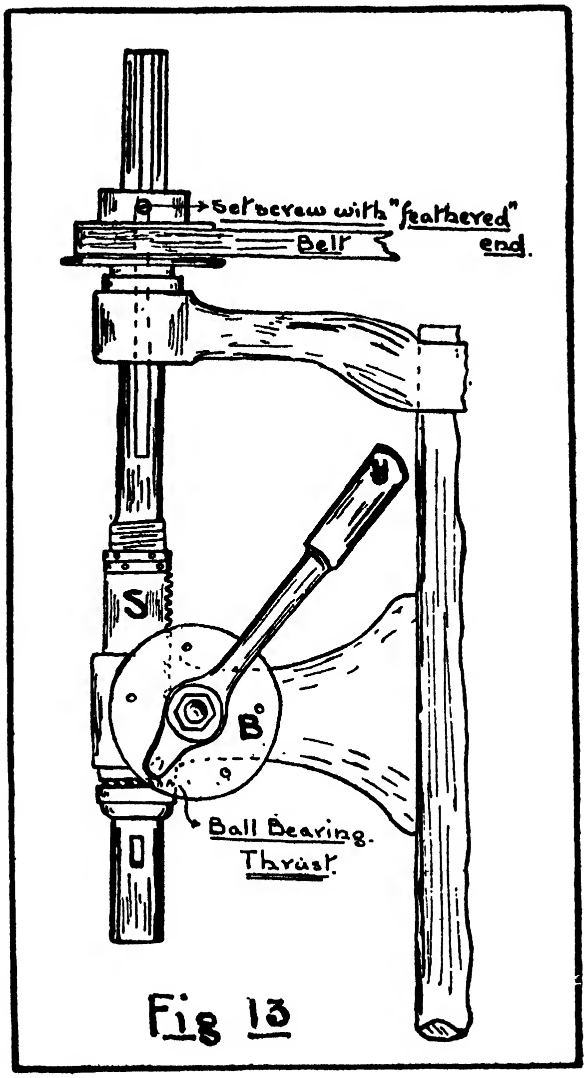


Fig 13

Great care must be taken, particularly when drilling thin metal, to feed very gently when the drill commences to protrude through the bottom side, else the lips will catch in the material, or the " flash " of the hole, and either break, or pull the work out of the hand. It is always advisable to have work gripped in a hand vise as shown in Fig. 15, or, if too large for that, in a machine vise.

When drilling holes up to $\frac{1}{2}''$ it is only necessary to indicate the centre with a centre punch mark, but for sizes above that, the circle should be marked off the exact size of the hole to be drilled, and 6 or 8 centre " pops " put round it. The

size of these pops must be as small as possible, never above $^1/_{32}$ of an inch, and should be made with a very sharp dot punch, see Fig. 14. This circle acts as a guide for accurate drilling. When the drill has made a countersink about two thirds the size of the circle, stop drilling and examine the work. If the countersink is exactly in the centre of the circle, continue drilling until the drill is cutting its full diameter. Again examine, when every pop around the circle should be half cut out, proving that the hole is correct.

Should the countersink be eccentric as in Fig. 14, the centre must be "drawn over." To do this a groove is cut with a diamond point, or fine half round chisel on the side towards which the drill must go, not letting the groove reach quite to the centre. The vector diagram shown at (*f*) Fig. 11 explains, in some degree, the reason for this. The resistance to cutting offered by the metal is less on the side of the hole with the groove cut out of it, consequently the drill "runs" towards it. Test again, examine, and repeat the cutting of the groove until the two circles are concentric.

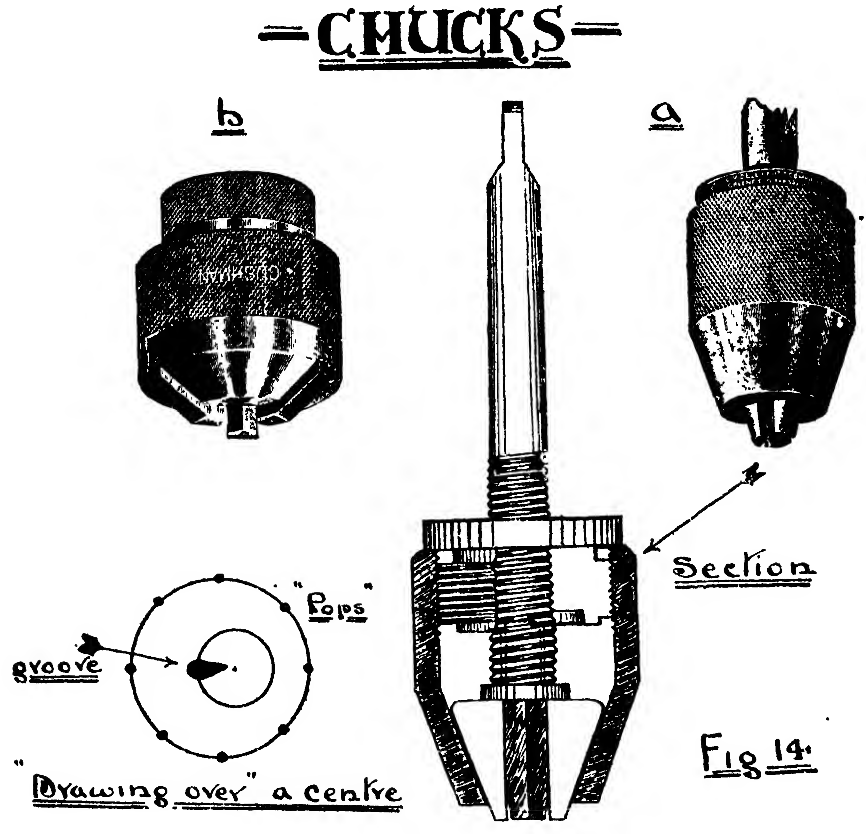


Fig 14.

LUBRICATION OF DRILLS.

The granular metals like cast iron or brass require no lubricant. They are best drilled dry. The cuttings from them come away in very small fragments, which, if mixed with oil would form a paste, clog the hole and tend to impede the rotation of the tool

Fibrous metals like wrought iron and mild steel require a plentiful supply of oil or other lubricant. These metals need more power for cutting, and as a great amount of the energy expended is converted into heat, the drills are liable to become overheated, and the temper drawn. Large drills frequently have a jet of lubricant (soap, soda and water) playing on them whilst drilling deep holes in wrought iron and steel.

Annealed cast steel should be drilled almost dry, the point of the drill being kept just greased. If too much oil is used it has the effect of hardening the steel, as the temperature is raised.

If, even after the application of oil, a drill squeaks, it is a sure indication that it either wants grinding (sharpening), or that it has insufficient clearance.

FURTHER PROJECTS.

Fig. 16 shows additional examples of fitting practice and bench work.

(1) Soldering Bit.

Made from $\frac{3}{4}''$ square or round copper rod. Old stay bolts from locomotive fire boxes answer the purpose admirably. A mild steel rod is bent at right angles and screwed into the copper. The tang at the other end is drawn down on an anvil to fit into a wooden handle, which affords a good example of wood-turning.

(2) Micrometer.

Material :—Mild steel for frame $\frac{3}{4}'' \times \frac{1}{8}''$ or $\frac{3}{16}''$.
" " " anvil $\frac{3}{4}'' \times \frac{1}{4}''$.
" " " spindle $\frac{1}{4}''$ diameter
Brass disc and calibrated bar.

The anvil is sweated on to the frame which can be bent cold. After the spindle has been screwed 20 threads per inch, the frame can be drilled and tapped to receive it. The circular disc is divided into five equal angles, and the lines both on this and the bar must be made permanent, either by etching or deep scratching with a sharp scriber, after which, red or black marking-ink should be rubbed into the grooves and allowed to set hard. Rivets are used to fix the bar in position, and the spindle end is rivetted over to secure the disc. The anvil end of the spindle is filed until the zero mark on the disc coincides with the zero mark on the centre line of the scale. The gauge will measure to .01 of an inch.

(3) Small Balance.

Material :—Strip sheet iron $\frac{5}{8}'' \times$ No. 16 gauge.
Mild steel for beam $12'' \times \frac{1}{2}'' \times \frac{1}{8}''$
Wrought iron rod $\frac{3}{16}''$ diameter.
Sheet Brass for cam and handle No. 16 gauge.
Sheet Copper for pans No. 22 gauge.

FIG. 15. WORK HELD IN HAND VISE WHILE DRILLING.

The frame can be bent to shape cold after the top hole for the bar has been drilled. The guide for the bar is drilled and rivetted in position. Before drilling the two holes for the cam spindle, fit a block of wood in the bend at the bottom of the frame, and mark off heights with a scribing gauge. The standard to carry the beam must be drawn down and bent as shown, and a groove cut in the bottom end with a hack saw to receive the edge of the cam.

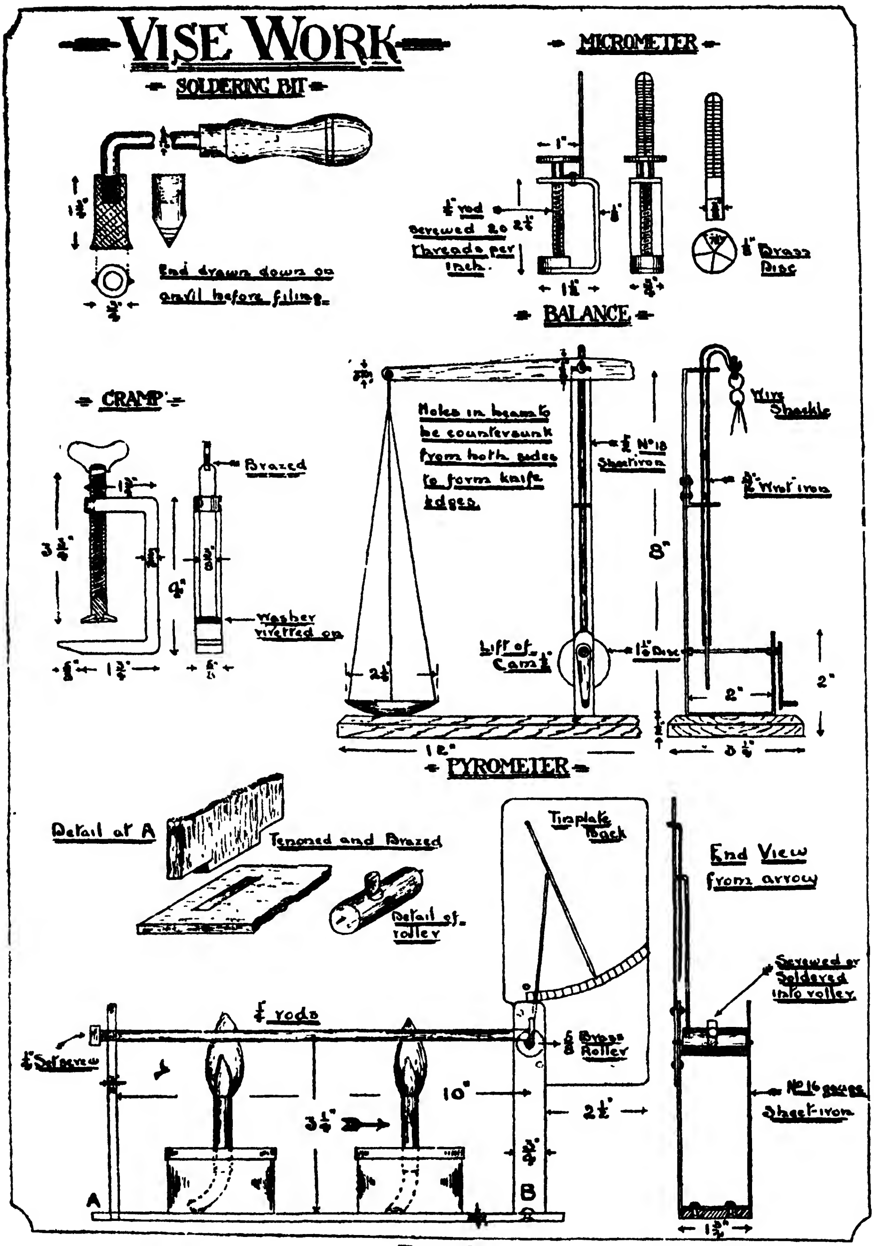


FIG. 16.

Shape the beam and make knife edges by countersinking at all points of support.

The pans are made from circular pieces of copper, hammered, with a round faced hammer or egg shaped mallet, into a dishing block. The cam, during half a revolution, raises the beam half an inch. It must therefore be drilled for the spindle $\frac{1}{4}''$ from the centre, after which the two can be soldered together.

Fitting small nuts on the ends of the spindle will be found to be the best method of adjusting it between the uprights of the frame.

The handle and spindle are rivetted and soldered together.

(4) CLAMP.

Material :—Wrought Iron for frame $\frac{3}{4}'' \times \frac{5}{16}''$.
Mild Steel for spindle $\frac{3}{8}''$ diameter.
„ „ for handle No. 13 gauge.

The frame must be bent and forged to size on an anvil and in the leg vise, and afterwards filed up. The spindle is screwed 16 threads per inch, and one end prepared for the handle, and the other for rivetting over on an $\frac{1}{8}''$ thick washer.

A template for the handle should be cut out of cardboard, laid on the metal plate and a line scribed round. Centre " pops " at intervals of $\frac{1}{2}''$ along this line will form a guide for filing, after the piece has been drilled and cut from the plate.

When the handle has been fitted into the groove in the spindle, braze the two together and clean off. For washers, it is advisable to have a mild steel bar 12 or 15 inches long turned to correct size, and discs about $\frac{1}{8}''$ thick parted off as required. Countersink washer for the rivetting and fasten to spindle, just allowing movement to take place between the two.

(5) PYROMETER.

Material :—Mild steel bar for base and upright at *A* $2''$ or $1\frac{3}{4}'' \times \frac{3}{16}''$.
No. 16 gauge Sheet Iron for support at *B* $10\frac{1}{2}'' \times \frac{3}{4}''$.
Brass rod for roller $\frac{7}{8}''$ diameter
Tinplate for indicator No. 1xx.
Brass tube $\frac{3}{8}''$ internal diameter for spirit lamps which are made from empty tins.
Screws, wire, rivets, etc.
Rods of various metals $\frac{1}{4}''$ diameter.

The base and end '*A*' can be cut, filed and squared in one piece, and afterwards cut with a hack saw.

Mark out and fit the tenon joint. Rivet the tenon slightly on the underside and braze.

Make support '*B*'; drill for rivets and fix in position. Centre the roller, and take a skimming cut off in a lathe with a hand tool. Before cutting to length, drill down the centre with a $^{4}/_{32}''$ drill to form sockets into which the spindles are to be soldered. Part off to length, making the ends slightly convex to lessen friction. The projecting part of the screw is then filed for the expanding rod to push against. Drill, tap, and fit screw in the roller. Mark off heights of set screw and roller spindle on the supports, and drill for same.

Tap the hole in '*A*' for the set screw. When the spindles have been soldered in the roller, it can be sprung into position. Set out the system of compound levers for the indicator, design and make a suitable back—one wire hangs loosely on this back and the other is soldered into the roller.

To Adjust the Apparatus.—The rods to be tested for relative expansion are cut off to length as accurately as possible. One end is filed square across, and the other has a conical recess drilled in it. The square end fits up against the shoulder filed on the screw fitted into the roller. The roller is also slightly hollowed out to form a seating for the rod.

The set screw in '*A*' is pointed to fit the end of the rods, and in addition to taking the thrust also allows of adjustment, being screwed either in or out for the initial zero reading.

Makers and Dealers in Drilling Appliances suitable for school equipments :

Messrs. George Hatch, Ltd., London.

„ Churchills Ltd., Manchester and Leeds.

„ Buck & Hickman, London.

„ Melhuish, Ltd., London

CHAPTER VI.

Screw Threads, Screwing and Tapping.

BEFORE entering upon a description of the various ways in which screw threads may be produced, it will be advisable to examine and discuss their geometrical and mechanical properties.

A screw is a simple machine, and as such is capable of doing work. This work may take the form of holding two or more plates together, or, it may be used for transmitting motion, as in the case of a lifting jack, or a spindle operating the slide rest of a lathe.

If a solid cylinder is rotated about an axis at a constant speed, and at the same time a cutting point, also moving uniformly travels along it, a curve, which is called a helix, will be cut in the cylindrical surface. (Fig. 17*a*). The helical curve may be defined as the path of a point moving round a cylindrical surface, in such a manner that its movement in the direction of the length of the cylinder shall be uniform with its movement around the surface of the cylinder. The distance moved, parallel to the axis during one revolution, is known as the pitch of the helix.

The apparatus illustrated in Fig. 18 (*a*) shows a screw thread to be a helical curve, which, if developed, is seen to be an inclined plane.

A wooden cylinder is mounted vertically on an axis. The plan of the cylinder on the base board is divided into any number of equal parts, say eight, and the lines from the centre, through these points, produced beyond the circumference. A piece of drawing paper is wrapped round the cylinder and fixed in position. Vertical lines, corresponding to the divisions in plan, are drawn on the paper.

On a vertical scale, the edge of which comes close up to the paper, is marked out the pitch, and this is divided into the same number of divisions as the cylinder.

When the cylinder is turned through $\frac{1}{8}$th of a revolution, the pointer rises $\frac{1}{8}$th of the pitch, and its position may be marked on the vertical line corresponding with '*I*.' If this be repeated at each division for a complete revolution, and the points then joined, the curve obtained will be a helix, which, if developed as shown on the right, becomes an inclined plane.

The base of the plane = circumference of cylinder $= \pi d$.
And height „ „ = the pitch $= P$.

The angle θ is constant with the horizontal for a given pitch, and can be obtained from a table of tangents.

$$\text{Tan. } \theta = \frac{\text{height of plane}}{\text{base of plane}} = \frac{P}{\pi d}$$

If instead of merely marking a line on a metal cylinder, a groove of definite shape is cut by a screw cutting tool, a screw thread will be formed. The shape of the thread will vary according to the purpose for which the screw is to be used.

FORMS OF SCREW THREADS.

In order that screwed elements shall be interchangeable, it is important that there should be uniformity in the sizes and angles of the same form of thread, and engineers in different countries have devoted much time and thought to effect agreement on this point.

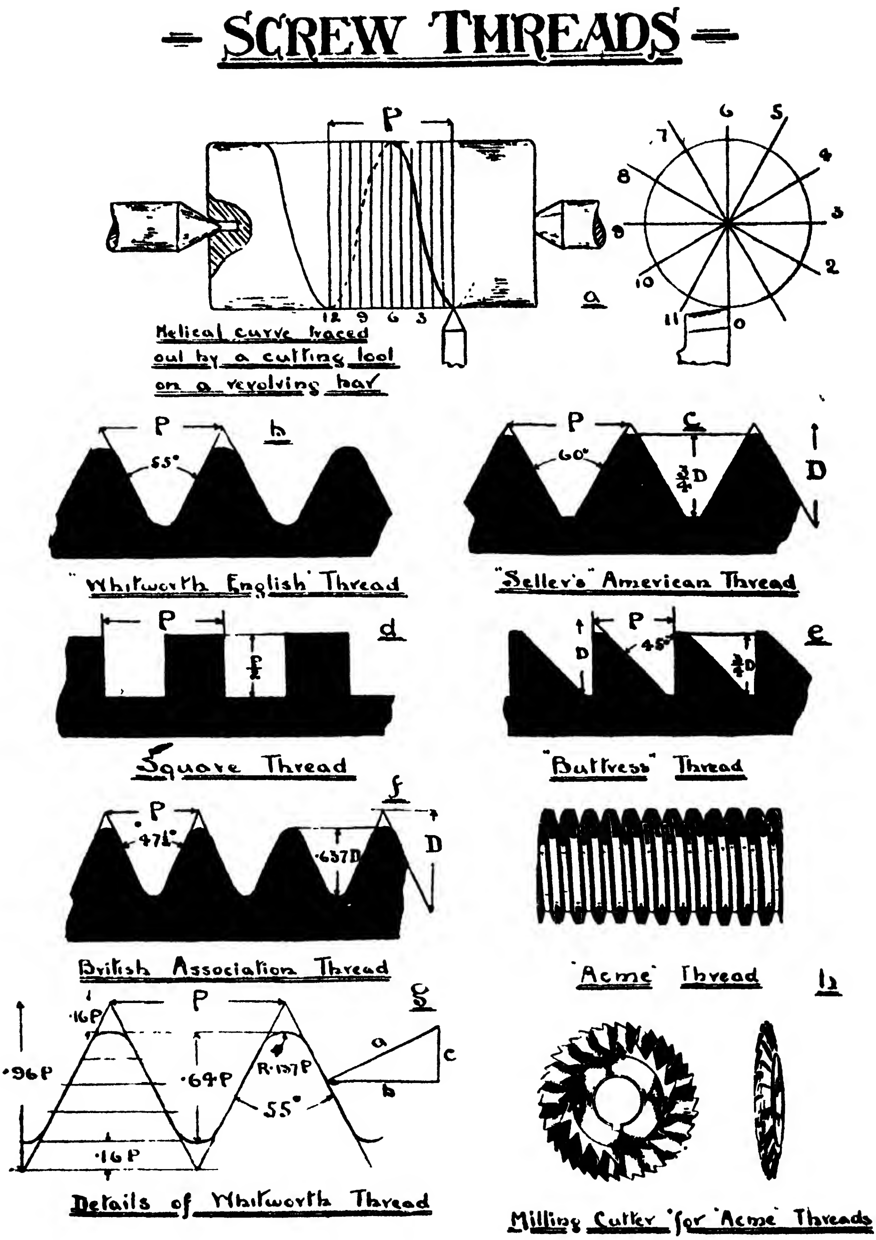


FIG. 17.

In 1841, in a paper read before the Institution of Civil Engineers, the late Sir Joseph Whitworth suggested the form of thread which has since been known as the "Whitworth English Standard Thread." The section of this thread is shown in Fig. 17 (*b*). It will be noticed that the enclosed angle between the two sloping sides is 55°, and also that the top and bottom of the thread are rounded off one sixth of the height.

Twenty years later an American engineer introduced the "Sellars" thread, which is the one in general use in the United States, see Fig. 17 (*c*).

This form of thread is an equilateral triangle, and, unlike the English Vee thread, has the crown and root of the thread made flat.

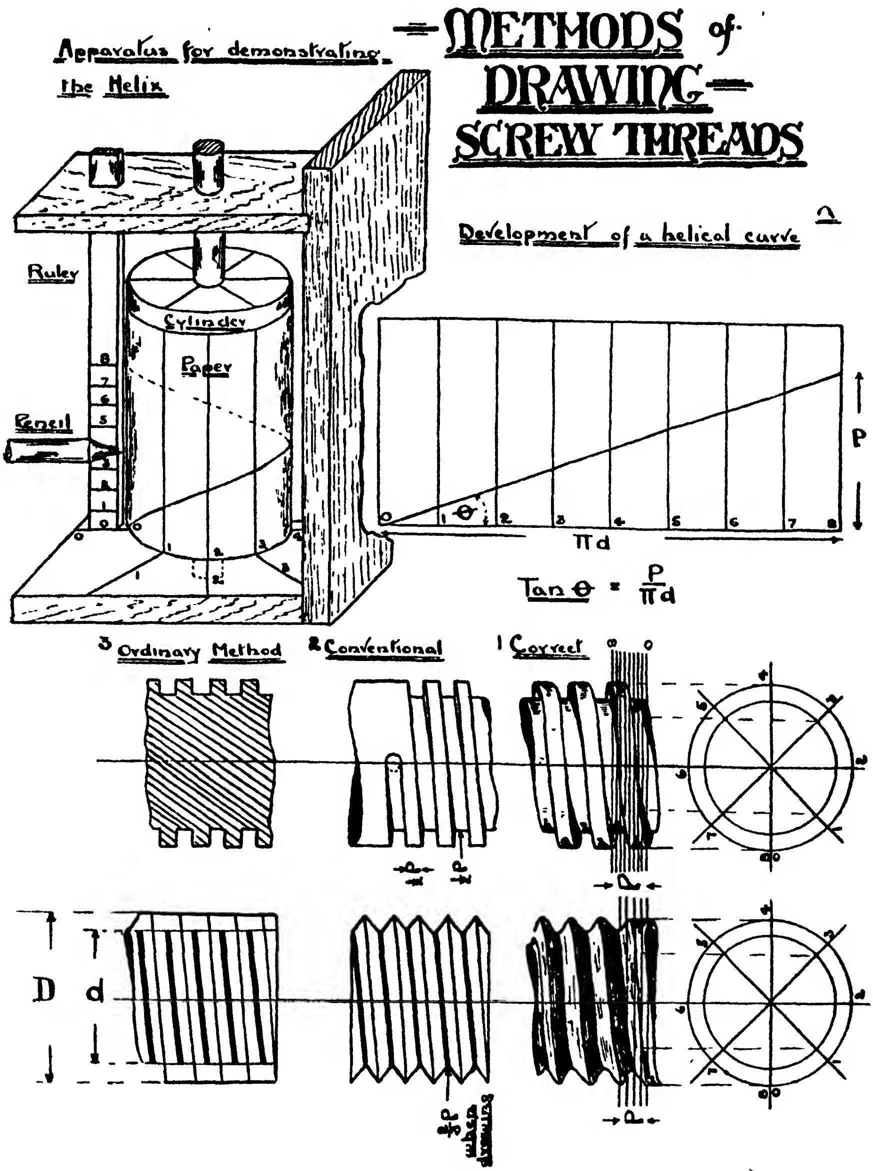


FIG. 18.

The "Sellars" thread is easier to produce than the "Whitworth," because the cutting tools are more simple to make, but there are other factors, particularly the sudden change in shape at the bottom of the thread, which makes it inferior to the "Whitworth" design.

"Vee" threads are strong by reason of their form, but the friction is great, because the screw surface is not at right angles to the force it is transmitting, and a bursting stress is set up in the nut, which is shown graphically at Fig. 17 (*g*).

The pressure put on the thread by the tightening up of a nut is represented by the vector *a*. This may be resolved into two components, one *b* representing the force acting parallel to the axis, and the other *c* the force at right angles to the axis. The latter force is the one tending to burst the nut, and offers frictional resistance to turning. The diagram shows the ratio of the lengthwise pressure to that of the bursting pressure, and it will be seen that any increase in the thread angle will increase the bursting effect on the nut. The stresses set up in the nut greatly decrease the tendency for it to become unscrewed or "slack back" owing to vibration, and for this reason 'vee' threaded bolts are used in all situations where movement is undesirable, *e.g.*, holding down bolts for engines and machines, studs for cylinder covers, etc.

To withstand the bursting stress nuts must be suitably designed. The formulae for all nuts to screw on 'Whitworth' 'vee' threads is as follows :—

Let D	=	Diameter of bolt.
Then $1\frac{1}{2}D+\frac{1}{8}''$	=	Distance across the flats.
$d = D$	=	Height of nut.
$2\frac{1}{4}D$	=	Diameter of washer.

Fig. 17 (*d*) shows a section of a square threaded screw used for transmitting motion. Its strength is less than that of the 'vee' thread, as the base has a smaller area to withstand shearing or 'stripping,' but the power obtained is much greater, as the surface of the thread is nearly perpendicular to the resistance to be overcome. The pitch is equal to a thread and a space, and the depth of the thread is equal to half the pitch in single threaded screws.

If a screw be required to transmit power in one direction only, as in the case of a vise, then the section of the thread may be made so as to combine the advantages of both the 'vee' and the square thread. Such a thread is termed a 'Buttress thread' Fig. 17 (*e*). The angle between the two sides is 45°, and the depth is equal to $\frac{3}{4}$ pitch.

A form of thread which has been made possible by the introduction of milling machinery is the 'Acme screw thread,' Fig. 17 (*h*). The space between the threads is milled out by a revolving cutter, and production costs are much lower than in the case of square threaded screws. Lead screws of lathes often have this type of thread, a great advantage being that the half-nut on the saddle of the slide rest can be engaged and released quickly and with little effort.

The thread shown at (*f*) is known as the 'B.A.,' and was introduced by the British Association in 1881. It is used on small screws for clockwork and scientific apparatus.

METHODS OF DRAWING SCREW THREADS.

In Fig. 18 the representation of screw threads is shown in various ways. To draw the thread correctly an end view of the spindle or bolt is taken, and circles drawn representing the top and bottom of the thread. These circles are divided into a number of equal parts, preferably eight or twelve. The pitch is set out on the side of the bolt, and divided into as many parts as the circles Lines are drawn through these points at right angles to the axis.

Where projectors from the points on the circles intersect the division lines of the pitch we have points on the screw thread, which is completed by drawing the curve through all the points. Curves parallel to the first one are drawn for each successive thread.

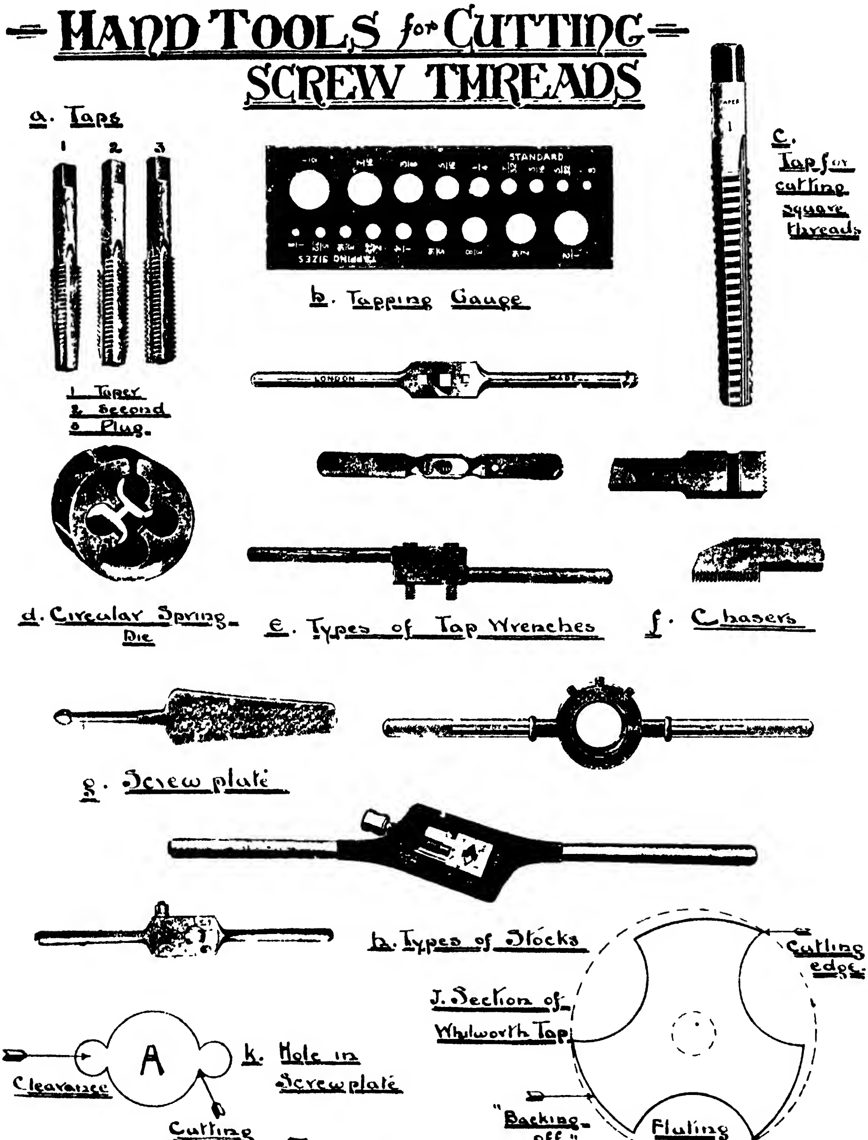


Fig 19

When it is required to show a thread in profile, a convenient method is shown at 2. The sides of the threads are straight lines, and instead of helical curves, straight lines are drawn joining the tops of the threads. Similar lines, drawn a little darker, represent the bottom of the thread. It will be noticed

that the ‘ vees ’ and ‘ squares ’ on one side of the spindle are half a pitch in front of those on the other side. The general method of representation is shown at 3. Thin lines are drawn for the top of the threads and thicker ones for the bottom, the bottom of the thread being supposed to be in shadow.

The pitch of the threads should be carefully set out before the cross lines are drawn, and the depth should be indicated, either by a line or by drawing the dark lines exactly the same length.

Should it be necessary to draw a number of ‘ Vee ’ threads to a large scale, a $62\frac{1}{2}°$ set square will be found very convenient for drawing the sides of the threads mechanically.

PRODUCTION OF SCREW THREADS.

The methods here described apply to the production of screw threads by hand tools only. Whilst being particularly suitable for the work of the handicraft room, the great cost of hand cut threads, as compared with those produced by automatic methods, has almost made the use of hand taps and dies an obsolete process in workshop practice. Only when tapping small holes in hard materials and for general jobbing work, are hand taps and dies used. But, as the aim of the handicraft room is not concerned with rapid or competitive production, the screw threads it is necessary to make can all be cut with these tools or in a screw-cutting lathe.

FORMATION OF SCREW THREADS.

Internal threads may be cut either :—

1. By means of taps. Fig. 19 (*a* and *c*).
2. By turning and chasing in a lathe.

External threads may be cut either :—

1. By means of a screw plate. Fig. 19 (*g*).
2. By dies held in a stock. Fig. 19 (*h*).
3. By turning and chasing.
4. By milling (see “ Acme ” thread).

Screw plates are only used for making the smallest sizes of threads from say $\frac{1}{4}''$ downwards. The plate is made of tool steel, hardened and tempered, after the holes are drilled and threaded. The chief fault of screw plates is that the position of the cutting edges is non-adjustable, and if an attempt were made to force a cut of the required depth on a rod at one turn, so much exertion would be required, that apart from the difficulty in getting the plate to start, the probability is that the rod would be twisted off. To avoid this the holes in a screw plate, for each size of screw, are in pairs (sometimes more), one being correct size and the other slightly larger. The large hole is first screwed down the rod marking out the thread, which is finally cut to the correct depth by screwing with the smallest diameter hole. The holes are slightly countersunk on the starting side to allow the cut to start, and cutting edges and clearance are provided by the method shown at ‘*A*’ Fig. 19 (*k*).

Screw plates are unsatisfactory in their cutting action, the thread being produced by pressure as much as by cutting. This squeezing of the metal often has the effect of increasing the diameter of the screwed portion of the rod.

For rods above $\frac{1}{4}''$ diameter, stocks and dies are used for cutting external threads, the cutting action of the dies being much more efficient than the screwplate. Fig. 19 (*h*) shows the common type of die and stock used. The die is made in two halves, each half being fitted into the stock by ' vee ' shaped grooves. Adjustment is obtained by turning the bolt in the stock backward or forward with a " tommy."

FIG. 21A.—SCREWING WITH " WHITWORTH " DIE.

Examination of a well made die will show that the cutting portion is considerably less than the circumference of the screw to be cut. The ends of each half of the die are ground off to form a relief angle and cutting edge, and two cuts on opposite sides of the circumference fulfil a similar purpose. Thus there are eight cutting edges, four of which act in each direction, allowing the die to be closed in at either end of the screw being cut. Dies ground away so as to leave small screw surfaces have a quick cutting action, but, having less bearing surface, do not guide so well, nor maintain so good a thread-form, as those with large screw surfaces. The screw surface should never be less than one third the circumference of the screw thread being cut.

What is known as the Whitworth improved die stock is also shown at Fig. 19 (*h*). Instead of two half dies, there are three (one guiding and two cutters). The guiding die has its smallest radius equal to the radius of the piece to be screwed, and the rake of the die agrees with the rake of the first trace of the thread cut on the rod ; thus the action of the guide is most efficient when it is most needed, *i.e.*, at the commencement of the cutting operation.

FIG. 21b.—FINISHING A THREAD WITH A CHASER.

Circular spring dies are an improvement on the older type, being much more rapid in cutting, are well guided, and afford good clearance. One is shown at (*d*) Fig. 19. Little adjustment is possible, nor is it necessary, the die cutting a well formed thread almost from the first cut. To open the die, slightly unscrew the two side screws in the stock, Fig. 19 (*h*), and screw up the middle one. To tighten the die on the rod being screwed, reverse the process.

It is a good plan when screwing a rod or bolt, to strike the thread with ordinary dies, and then run it down with the circular one. When cutting a

thread on a rod the end of the piece should be bevelled off with a file, the die being just made to grip the metal, and a light cut taken. The die may then be tightened up and another cut taken. This process is repeated until the thread will engage with the element to receive it.

It may be noticed during cutting that the die becomes tight on the rod. This is because the shaving coming from the metal is not being broken; and to continue cutting will certainly result in a broken or stripped thread. The die should be turned back a thread or so until the breaking of the cutting is felt; this should be repeated every few turns. Care must be taken to see that the faces of all dies are kept square with the axis of the work.

TAPPING.

For screwing internal threads the tools used are called taps, Fig. 19 (*a*), which are held and turned in some form of tap-wrench, Fig. 19 (*e*). For each size of screw thread, taps are made in sets of three :—Taper, intermediate or second, and plug. The taps used for cutting dies and chasers are known as master-taps and hobs.

TAPPING SIZE.

When a hole is to be screwed, in order to obtain a 'full thread' the diameter of the hole drilled to receive the tap must be the diameter of the bottom of the tap or male thread. This is known as the tapping size. The gauge shown at (*b*) Fig. 19, can be used to check drills for standard and tapping size holes from $\frac{1}{8}''$ to $\frac{1}{2}''$, or the tapping size for any screw thread may be determined as follows :—In the details of the Whitworth thread, (*g*) Fig. 17, it will be noticed that the total depth of the thread is 0.96 P; this is called the theoretical depth of the thread, and in such a form would be quite unserviceable. A sixth of the depth is rounded off at the top and bottom leaving a depth of 0.64 P, being the working depth of the thread. Multiply this depth by 2 and we obtain the formula d = D—1.28P. See Fig. 20.

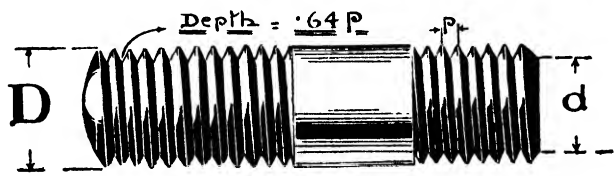


Fig. 20.

As twist drills increase in size by $^1/_{64}$th, it is more convenient to use the fraction 1.25 P when calculating tapping sizes.

$$P = \text{No. of threads per inch} = \frac{1}{N}$$

Example.—What is the tapping size of a hole to be screwed to receive a $\frac{3}{8}''$ bolt or spindle?

$$\begin{aligned} d &= D - 1.25\ P. \\ &= \tfrac{3}{8}'' - (1\tfrac{1}{4}\ P) \text{ where } P = \frac{1}{N} = \tfrac{1}{16}. \\ &= \tfrac{3}{8}'' - \tfrac{5}{4} \times \tfrac{1}{16}. \\ &= \tfrac{3}{8}'' - {}^5/_{64}''. \\ &= {}^{19}/_{64}'' \text{ Size of drill required.} \end{aligned}$$

The taper tap, which is ground plain for about one-third of its length, is placed upright in the hole, and pressed and turned gently to start the thread. If the hole goes through the metal the taper tap can be taken right through, and no other may be needed, but, in screwing a "blind" hole, the second, and then the plug must be used to carry the thread to the bottom of the hole. Care must be taken that the axis of the tap is kept in the centre of the work, and that the turning is done uniformly to avoid snapping off the shank. The remarks about the breaking of the metal being cut during the screwing with dies apply equally to taps.

FIG. 21C.—SCREWING WITH A CIRCULAR DIE.

The use of oil is also very important during the screwing of all metals, with the exception of brass.

For efficient cutting, taps must be properly "backed off," to give clearance behind the cutting edge. The edges are formed by a method known as "fluting," which gives a cutting angle of about 90°. The Whitworth Standard

tap has three flutes, which are formed by dividing the cross section into a regular hexagon. Three alternate divisions are fluted out in the form of semi-circles, and the three remaining ones are threads, see (J) Fig. 19.

Taps breaking off short in holes are a great source of trouble. The only possible way of extracting the broken piece is to heat it sufficiently to draw the temper, and, when cool, to drill a small hole through it, and then a larger one, and so on until the piece can be chipped out, generally a lengthy and unprofitable occupation.

FIG. 21d.—TAPPING A "BLIND" HOLE.

Stocks and tap wrenches are made of mild steel with their working parts case hardened to resist wear. Taps and dies are made of high grade cast steel hardened and tempered. The colour of the oxide in both cases is allowed to approach a medium straw colour, and the tools are then quenched in lard oil.

TURNING AND CHASING.

The cutting of screw threads of large diameter by hand is a tedious process, requiring heavy tools and considerable physical exertion. When above $\frac{1}{2}''$ in diameter, much the better plan is to cut the thread in a screw-

cutting lathe and finish with a chaser. These processes will be described under the heading of Lathe-work. Fig. 21 *a*, *b*, *c*, and *d*, shows various screwing operations being carried out by boys 14 years of age.

I. WHITWORTH STANDARD THREADS.

TABLE OF TAPPING SIZES.

Diameter of Bolt.	Threads per Inch.	Tapping Size.
$\frac{1}{8}''$	40	$\frac{3}{32}''$
$\frac{3}{16}''$	24	$\frac{9}{64}''$
$\frac{1}{4}''$	20	$\frac{3}{16}''$
$\frac{5}{16}''$	18	$\frac{1}{4}''$
$\frac{3}{8}''$	16	$\frac{19}{64}''$
$\frac{7}{16}''$	14	$\frac{23}{64}''$
$\frac{1}{2}''$	12	$\frac{13}{32}''$
$\frac{5}{8}''$	11	$\frac{31}{64}''$
$\frac{3}{4}''$	10	$\frac{5}{8}''$

II. BRITISH ASSOCIATION STANDARD THREADS.

TABLE OF TAPPING AND CLEARANCE SIZES.

No. of B.A. Screw.	No. of Clearing Drill.	No. of Tapping Drill.
0	13	12
1	3	19
2	15	24
3	20	30
4	27	34
5	30	40
6	33	44
7	39	48
8	43	51
9	49	53
10	50	55

BRITISH STANDARD FINE THREAD. $\frac{1}{4}''$ UPWARDS.

TABLE OF TAPPING SIZES.

Diameter of B.S.F. Screw.	No. of Threads.	Tapping Size.
$\frac{1}{4}''$	26	$\frac{13}{64}''$
$\frac{9}{32}''$	26	$\frac{15}{64}''$
$\frac{5}{16}''$	22	$6\frac{1}{2}$ m/m.
$\frac{3}{8}''$	20	$\frac{5}{16}''$
$\frac{7}{16}''$	18	a
$\frac{1}{2}''$	16	$\frac{27}{64}''$

For fine threaded work the British Engineering Standards Association recommends for all sizes below $\frac{1}{4}''$ the B.A. standard, and for all sizes above and including $\frac{1}{4}''$, rising by $\frac{1}{16}$ths, the Whitworth thread form of screw but in a series of finer pitches, Table III. abbreviated B.S.F.

CHAPTER VII.

A JUNIOR TECHNICAL COURSE IN FITTING PRACTICE

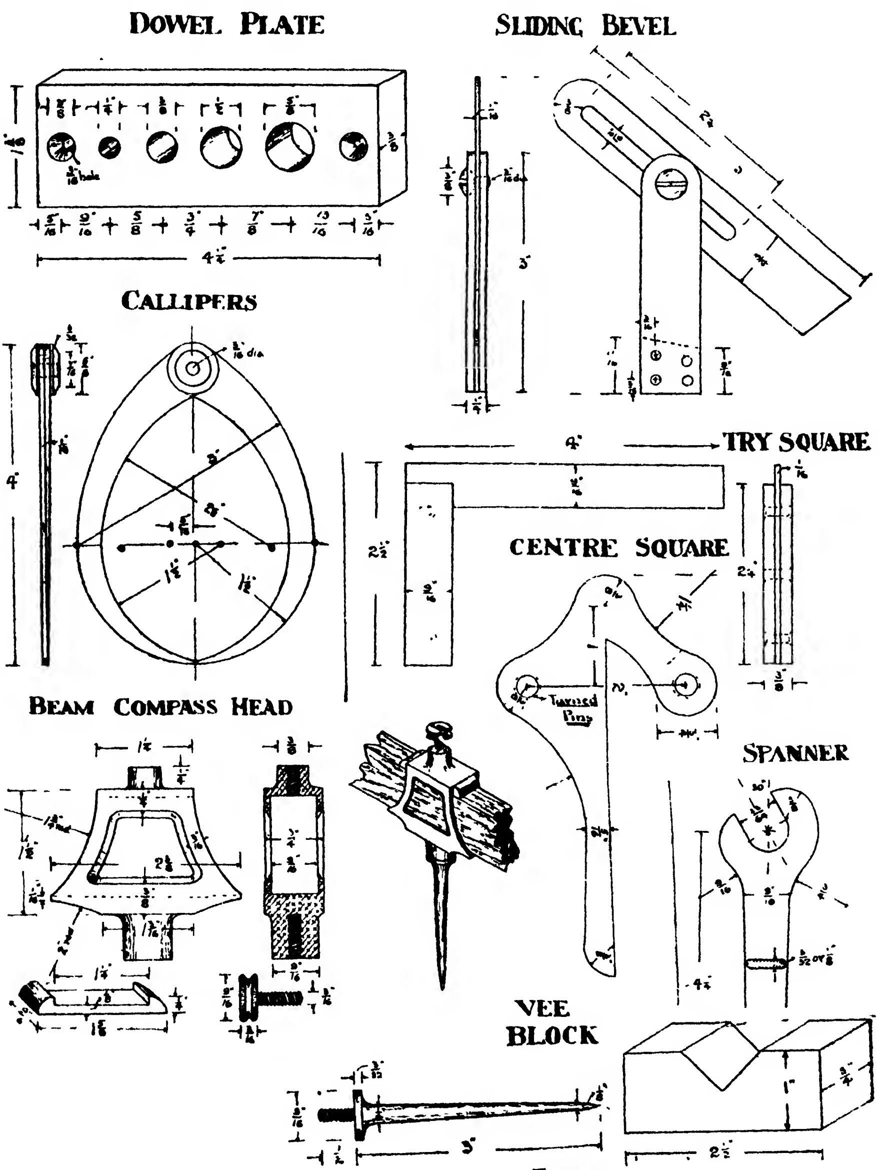


Fig 22

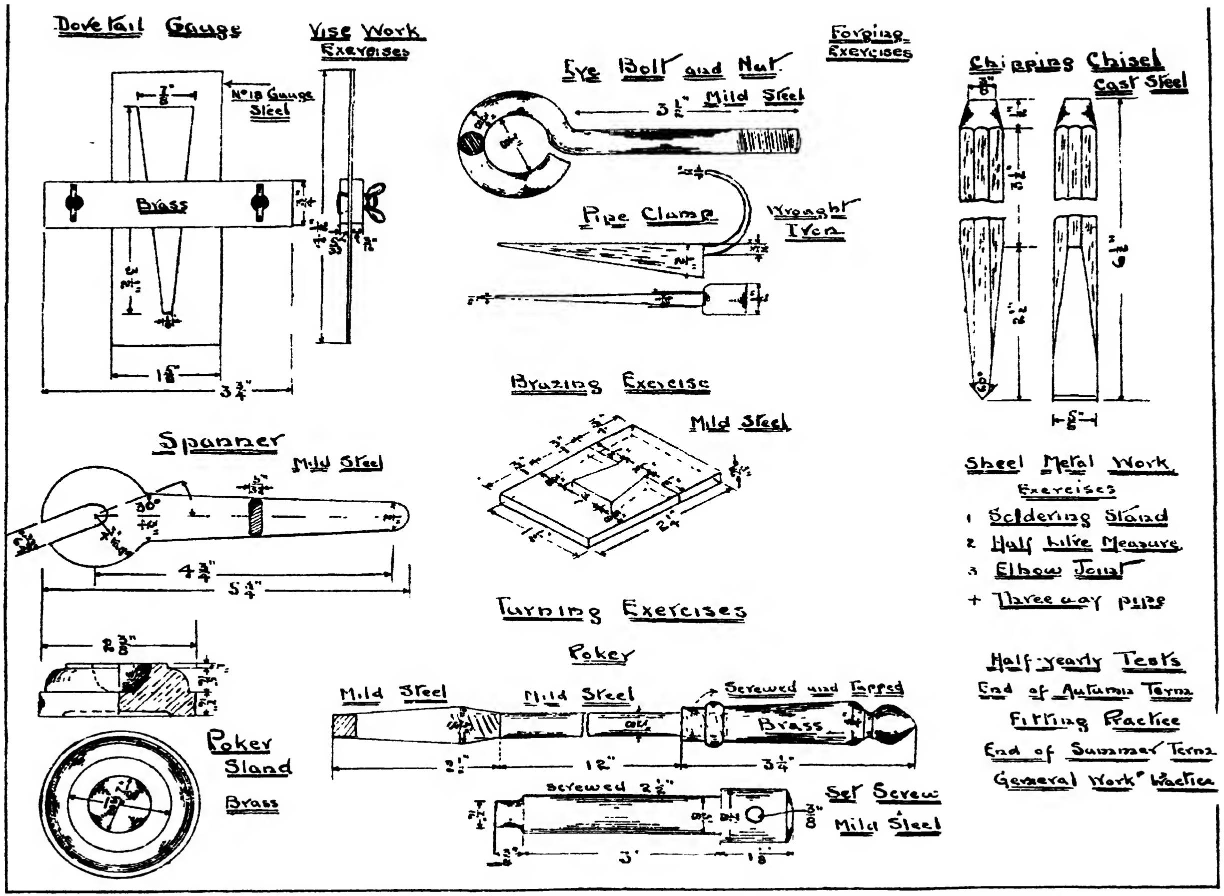


FIG. 22a.—WORKSHOP PRACTICE. FIRST YEAR ENGINEERING COURSE IN A SECONDARY SCHOOL.

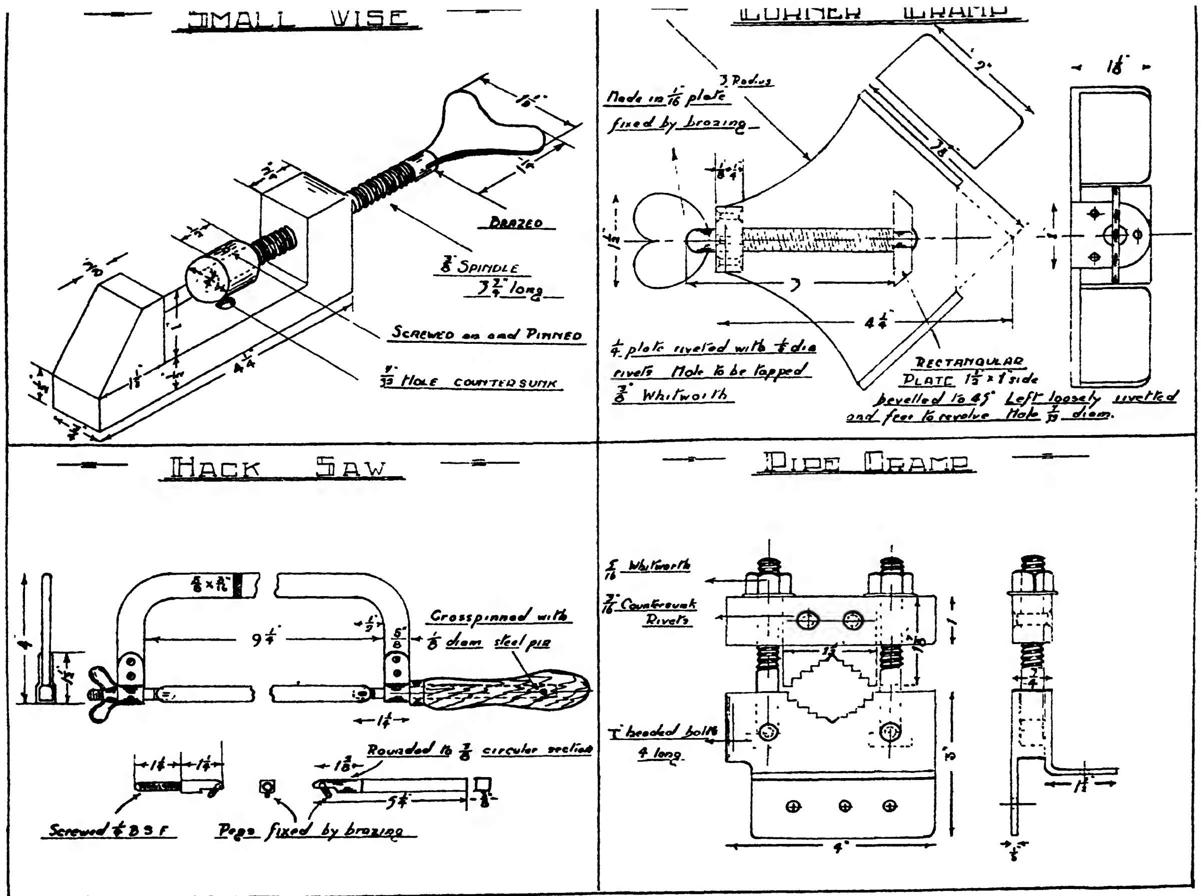


FIG. 22b.—FITTING PRACTICE. TOOL MAKING. CITY AND GUILDS TESTS.

A Junior Course in Fitting Practice.

AN examination of the drawings will show a marked contrast between the work of the Handicraft Class and that of a Vocational Course. The freedom and opportunity for expression, which should characterise the former, must now be very considerably modified. A higher standard of hand skill and technique, demanding more sustained effort, is required, and new and strict workshop methods must be introduced, in order to secure a greater degree of accuracy.

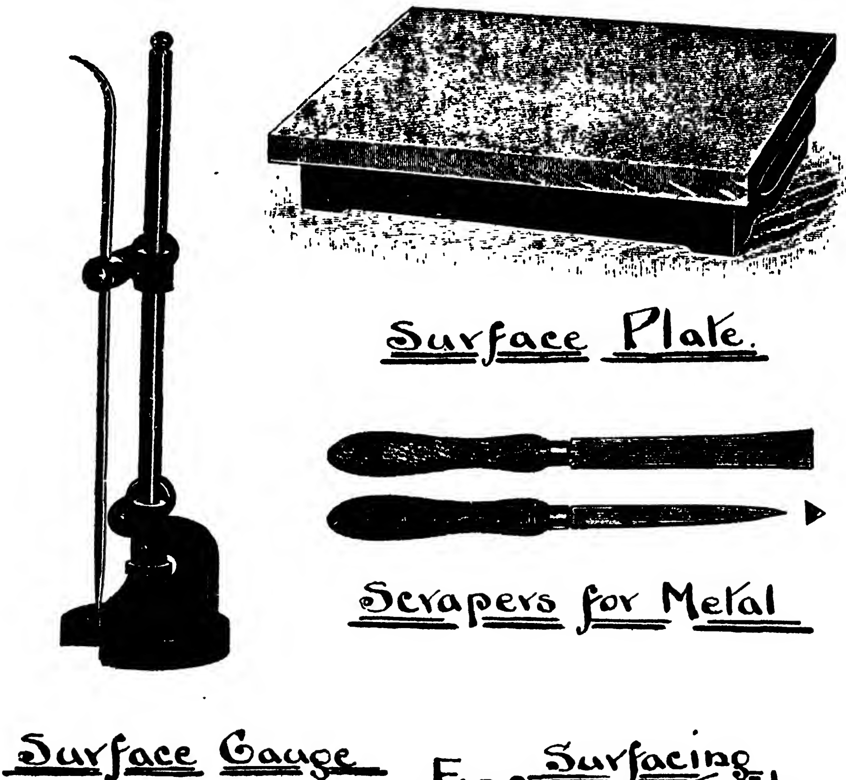


Fig. 25. Surfacing Tools.

The test of craftsmanship, in vise-work and fitting practice, is the ability to produce true surfaces. The surface plate made by Sir Joseph Whitworth in 1840 was the first systematic attempt to obtain a perfectly plane surface. He called it a " true plane," and although truth in connection with measurement is relative, surface plates, as used to-day, are a very close approximation to exact truth.

With his limited skill the young student can only be expected to attain a fair degree of accuracy, but opportunity should be afforded to pupils in Central and Junior Technical Schools to carry out work demanding the use

of surfacing tools (Fig. 23), not only with the aim of improving their craft knowledge, but in order that they may appreciate the patient effort of master craftsmen, that has made such a commonplace experience of to-day as the interchangeability of machine parts, none the less a wonderful technical achievement.

The drawings in Figs. 22, 22a and 22b afford examples of suitable projects The chief points to be noted are :—

FIG. 24.—SPREADING A RIVET HEAD.

I. Wide surfaces are now filed and sometimes scraped. In previous examples only edges and ends were so treated.

II. Marking out for parallelism, which is now done on the surface plate with a surface or scribing gauge.

NOTE.—As the lines made by the gauge point are difficult to see on bright steel, the material should be either rubbed with a piece of copper sulphate (copperas or bluestone) or, preferably, painted with a solution of it. A film of copper is deposited on the steel, and lines drawn on it can easily be seen.

III. Lines that have to be worked to with files and cutting tools are "popped" at intervals of $\frac{1}{2}''$ with a dot punch. When the work is finished to dimensions half the punch mark will have been removed, and half should remain showing. (See chapter on Drilling). If the punching is done carefully and lightly, such traces of the marks as are left after final draw-filing are not objectionable.

BOOKS FOR REFERENCE.

The Principles of Fitting—Horner.

Workshop Appliances—Shelley.

Complete Practical Machinist—Rose.

Engineering Tools and Processes—Robson.

RIVETS AND RIVETTING.

Rivetting is the commonest form of fastening used by metal workers. The property of malleability possessed by all metals makes it possible :—

I. To stretch the metal and form heads of varying shapes on pieces of round bars, for the purpose of holding plates together, as in girder work, shipbuilding, tank and boiler-making, and structural work generally. The rivets used in this class of work are of large diameter, and the heads have to be formed whilst the metal is hot.

II. By careful arrangement, to make the rivet serve the dual purpose of acting as a fastening and also as a means of embellishment, a method often adopted by coppersmiths, silversmiths and art metal-workers. (Fig. 26). The rivets being small, and very malleable, are hammered whilst cold. " Cold " rivetting is also performed by tinsmiths and sheet metal workers.

III After reducing the ends of rods and bars, and fitting into holes to receive them, to rivet over the projecting shank. Wrought iron construction as seen in gates, grills, screens, hanging signs, etc., affords numerous examples.

IV To utilise the rivetted joint in tool making for holding a pair of elements together, and at the same time allow limited movement. Snips, pliers, tongs, callipers, etc., are common examples.

FORM OF RIVET HEADS.

Fig. 25 shows the four different shapes of rivet heads in everyday use. The dimensions are in terms of the diameter ' D,' but instead of committing these to memory, many draughtsmen use the method illustrated at (*A*) Fig. 25 for drawing rivet heads.

SNAP HEAD.—Radius equals $\frac{3}{4}$D drawn from a centre $\frac{1}{8}$D below the head of the rivet.

PAN HEAD.—Each side of the head is drawn at right angles to a line, which joins the edge of the rivet head to the centre mentioned above.

CONICAL HEAD.—The sloping sides are drawn at 30° with the plate surface.

COUNTER-SUNK HEAD.—Usually drawn at 45°, but as the countersinking is often done by twist drills the angle in practice is generally more acute.

SHAPING THE HEADS.

When the shank of the rivet has been placed through the holes in the plates, the head already formed is well supported, and the projecting part is hammered over with the round peen of a rivetting hammer, Fig. 26, care being taken not to split the metal. When the head is of approximate shape it is finished off with a rivet set or " snap." Fig. 26. The shape of the recess in the snap gives the rivet head the form and neat appearance required.

As previously stated, in the case of large rivets this operation must be carried out when the rivet shank is hot. Not only is the shaping done quickly and better, but the contraction during cooling brings the plates into closer contact.

In the handicraft room the thin material, and the comparatively small rivets used, make it possible for all rivetting to be done "cold," and many of the rules, which must be strictly adhered to in industrial practice, may be considerably modified. In order, however, to safeguard the student from falling into the error of imagining that this branch of metalwork is a haphazard business, some instruction should be given, particularly in Central and Junior Technical School Courses, in the principles underlying the sound design of rivetted joints, attention being given to the nature of the stresses acting upon them, and investigation made into possible causes of failure.

LAP.

On reference to diagram '*B*,' Fig. 25, it will be seen that if the "lap" is made too small, the plates, when subjected to a tensile stress, are liable to be torn along '*AB*.' To prevent this, the minimum distance from the edge of the rivet hole to the end of the plate should equal '*D*,' or, for a single rivetted lap joint, like the one shown in the figure, the lap should not be less than '3D.' If on the other hand the lap be made excessive, the plates will open at the ends owing to the pressure and contraction of the rivets.

DIAMETER OF RIVET.

Under the action of the same stress, the rivet, if of too small a diameter, will be sheared or cut along the line '*CD*.' For thin plates it is customary to use rivets having a greater cross sectional area than is necessary to resist shearing. One reason for this is that rivets of small diameter are liable to have the heads broken off, owing to the contraction on cooling. Boiler-makers seldom use rivets less than $\frac{3}{4}''$ diameter. The correct diameter of rivet for any thickness of plate is determined by Professor Unwin's formula $D = 1.2\sqrt{t}$ or as it is sometimes expressed—

$$D = \sqrt{1.44t}$$

where t = the thickness of the plate in inches.

The diameter can also be obtained graphically by the method shown at '*C*' (Fig. 25). On a line $(t+1'')$ in length draw a semi-circle, and at (a) erect a perpendicular to cut the semi-circle in b. Divide a, b, into 5 equal parts and continue the line to '*C*,' making bc equal to one of these parts; then ac is the diameter of the rivet for that thickness of plate.

When it is impossible to obtain rivets of just the calculated size, it is usual to work to the nearest sixteenth larger; for instance, the exact size of rivet for $\frac{3}{8}''$ plates is 73, but $\frac{3}{4}''$ rivets are used.

PITCH OF RIVETS.

The distance '*P*' between the centres of the rivets is called the pitch, and if this be made too small the joint may fail by the tearing of the plates between the holes as at '*E*' and '*F*.'

Assuming the shearing strength of the rivet to be equal to the tensile strength of the plate, in a well-designed rivetted joint, the area of the plate between the holes should be equal to the cross sectional area of the rivet.

Thus, for a single rivetted lap joint, see *d* Fig. 25.

$$(P-d)t = \frac{\pi d^2}{4}$$
$$= .7854d^2$$
$$P-d = \frac{.7854d^2}{t}$$
$$\text{and } P = \frac{.7854d^2}{t} + d$$
$$\text{or } P = \frac{\pi d^2}{4t} + d$$

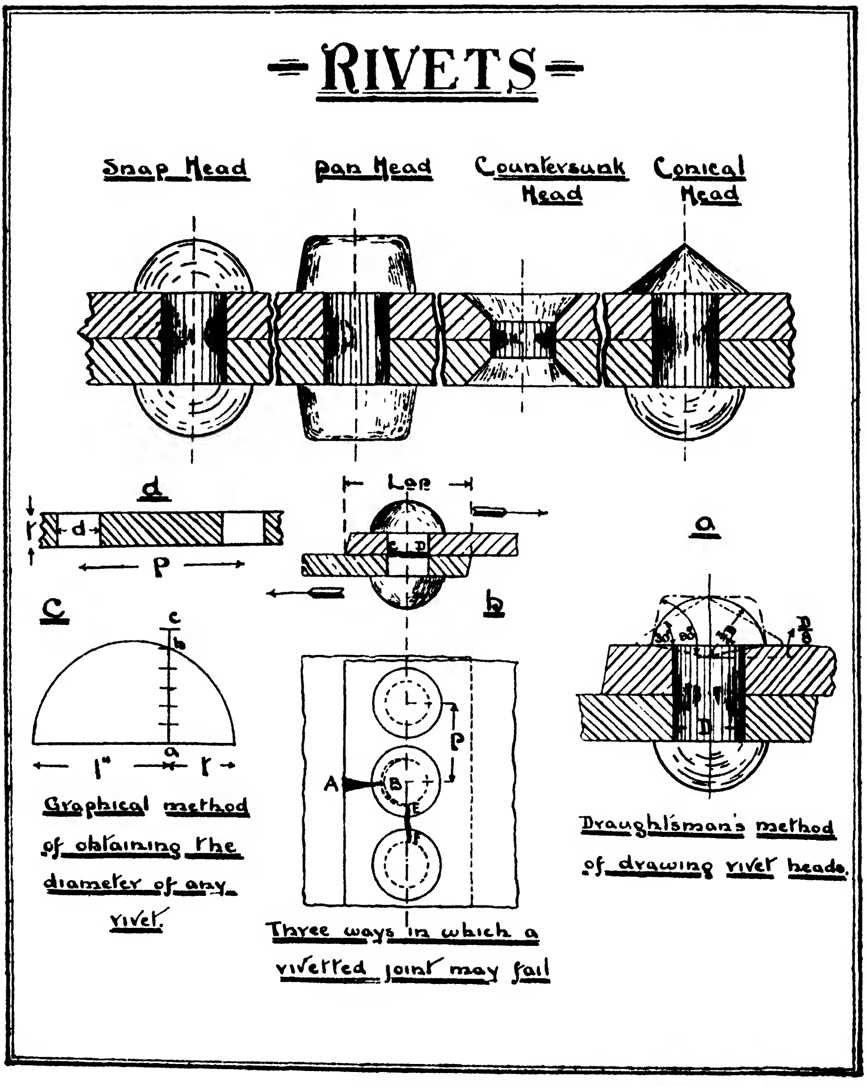


FIG. 25.

When rivetting two pieces of metal plate together, it is advisable to mark out and drill, or punch, all the holes in one plate, and only one hole in the other piece. Insert a rivet and fix the plates. The holes made in No. 1 will now indicate the position of those to be made in No. 2, and the drilling may be performed rapidly. No reamering will be necessary, as the holes, by this method, are in correct register.

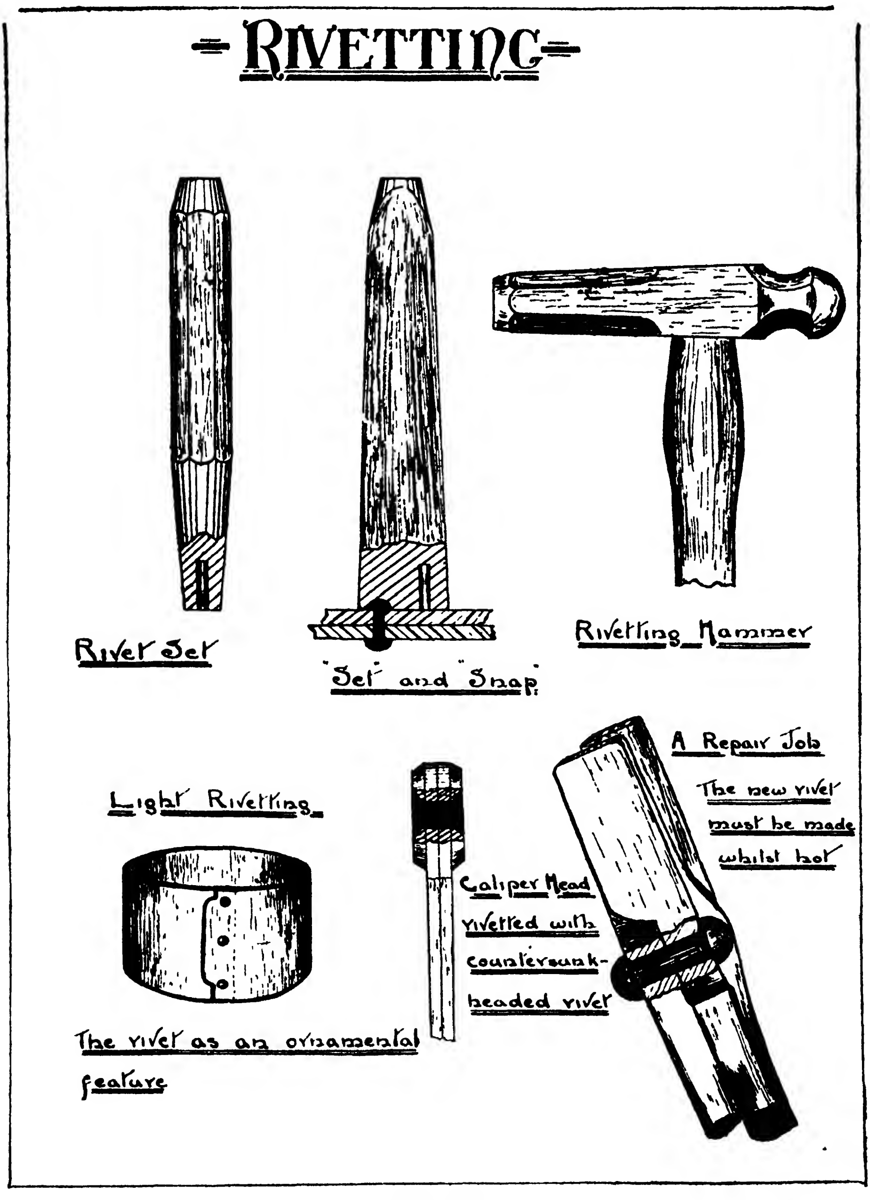


FIG. 26.

CHAPTER VIII.

Forgework and Smithy Practice.

NO branch of handicraft has a higher educational value than Forgework. The acquirement of dexterity in any craft is accomplished in only one way :—by active trial and error ; but, whereas in all other crafts new tools and mechanical aids are continually being brought to the service of the worker, the smith is still dependent on hammer and anvil. For the rest he must rely on sound judgment and craft knowledge learnt by imitation and patient observation.

An African proverb says " No one teaches the smith's son his trade ; God shows him how," which, interpreted, means that upon the faculty of observation depends the boy's success in his father's trade.

FIG. 27.

So with the boy at school ; no occupation demands such mental alertness, or taxes initiative more, in arriving at rapid yet sound conclusions. The effect of each hammer blow must be considered in relation to the one that is to follow ; and, in addition to its craft value, the working of hot iron and steel affords excellent opportunities for the application of chemistry, physics, and mechanics to work-shop practice. " Strike while the iron is hot " has many applications in everyday life, and when followed literally has an important educational significance.

EQUIPMENT.

The equipment necessary for the exercise of a course in this craft need not be expensive. In the plan of the metalwork room, Fig. 1, two fires and two anvils are shown. These will accommodate a group of four pupils, whilst Fig. 27 is a photograph of a room equipped as a smithy where it is possible to have a dozen students engaged in forging.

FORGES.

Thére are several types of light forges on the market now that are suitable for school practice, the simplest being the one shown at Fig. 29. Built of iron plates and angle irons rivetted together, it answers all purposes admirably. The most important question to be decided is "How to supply the blast?" If a blower driven from the main shaft is installed, a blast pipe leading from it to the nozzle, and fitted with a turn cock, is all that is necessary. Some objection might be raised to this arrangement, firstly on the ground that blowers and fans are noisy, and interfere with work going on in other parts of the room: and secondly, because it is felt that students should do all the operations themselves. By having to do the "blowing" by hand, the pupils' attention will be continually directed to the fire, which will be maintained in a better condition for working, while the danger of burning the nozzle of the blast pipe will be minimised. If hand blowing is decided upon, the air blast can be supplied by means of a mechanical fan attached to the back of, or underneath, the fire, see Fig. 29. The old-fashioned method of bellows blowing, traditional to the craft, is now out-of-date; the draught is blown into the fire in puffs, and the pressure is never constant.

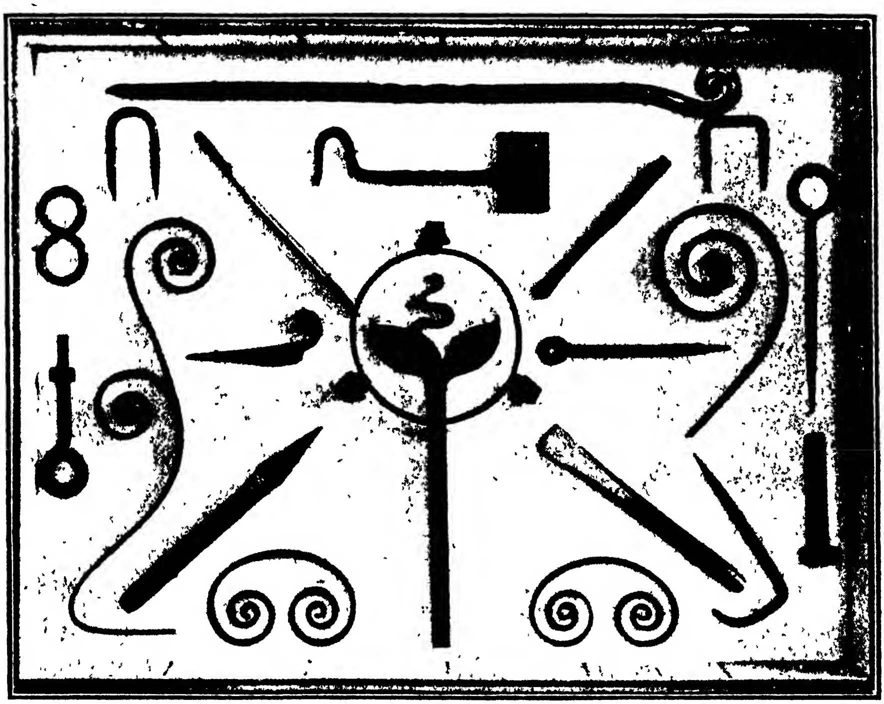
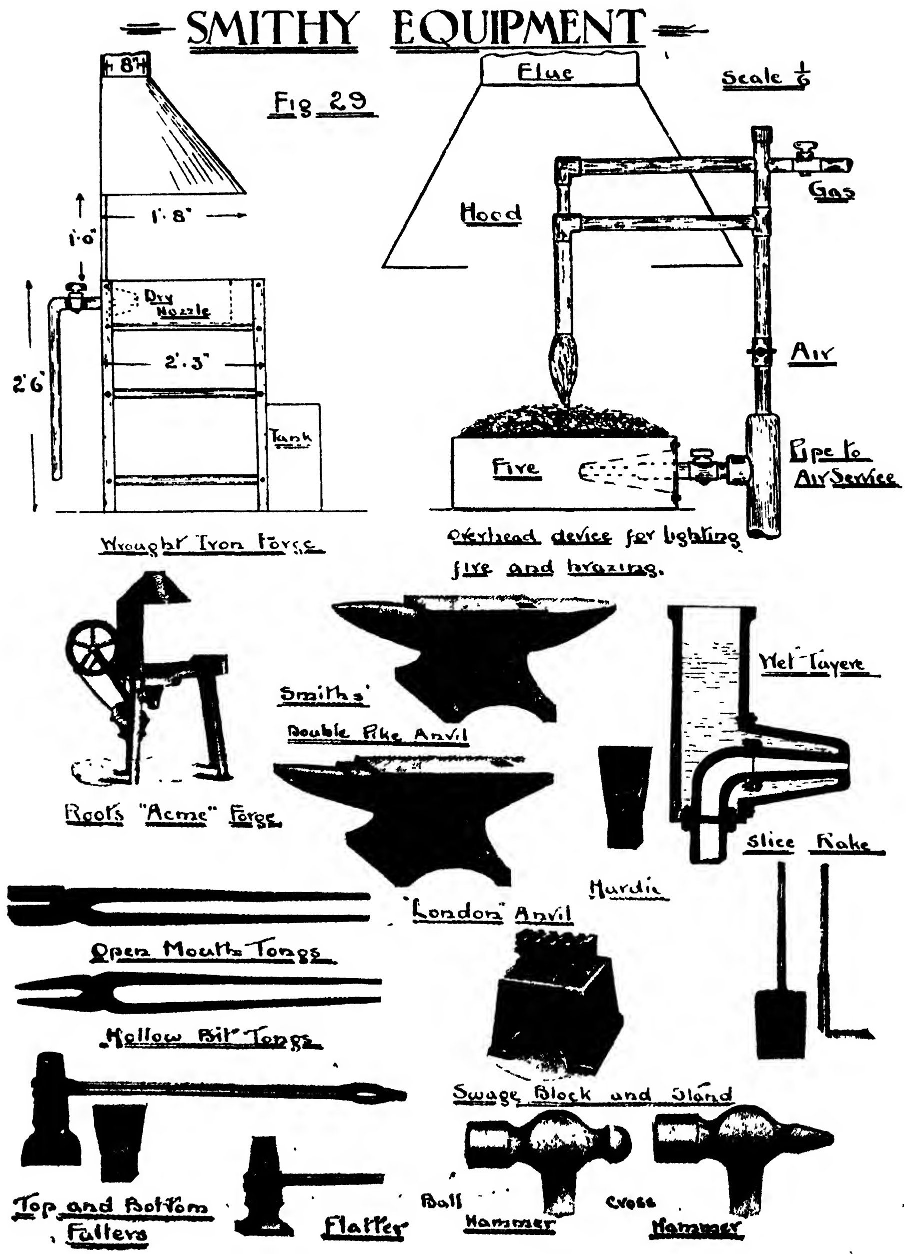


FIG. 28.—A COURSE OF FORGING AND SMITH'S WORK.

The blast may enter the fire either at the bottom or from the back. Fig. 29 shows a forge fitted with a dry tuyere (Tuyau—a pipe) at the bottom of the fire. The nozzle is protected from the heat of the fire by a fireclay jacket which requires periodical renewal. Careful usage is necessary, or burnt iron and slag will choke the air passages. With young students, it has been found

preferable to admit the air into the back of the fire, the blast nozzle projecting about 7″ from the back plate of the hearth, and the orifice 3″ from the bottom. Large forges, and built up smith's hearths are fitted with "wet tuyeres," see Fig. 29. The air pipe, called by the smith a "tue iron," being water jacketed, is always comparatively cool, and the nozzle has a much longer life than a "dry" one. Dry nozzles, like the one shown in Fig. 29, require renewal every two to three years.



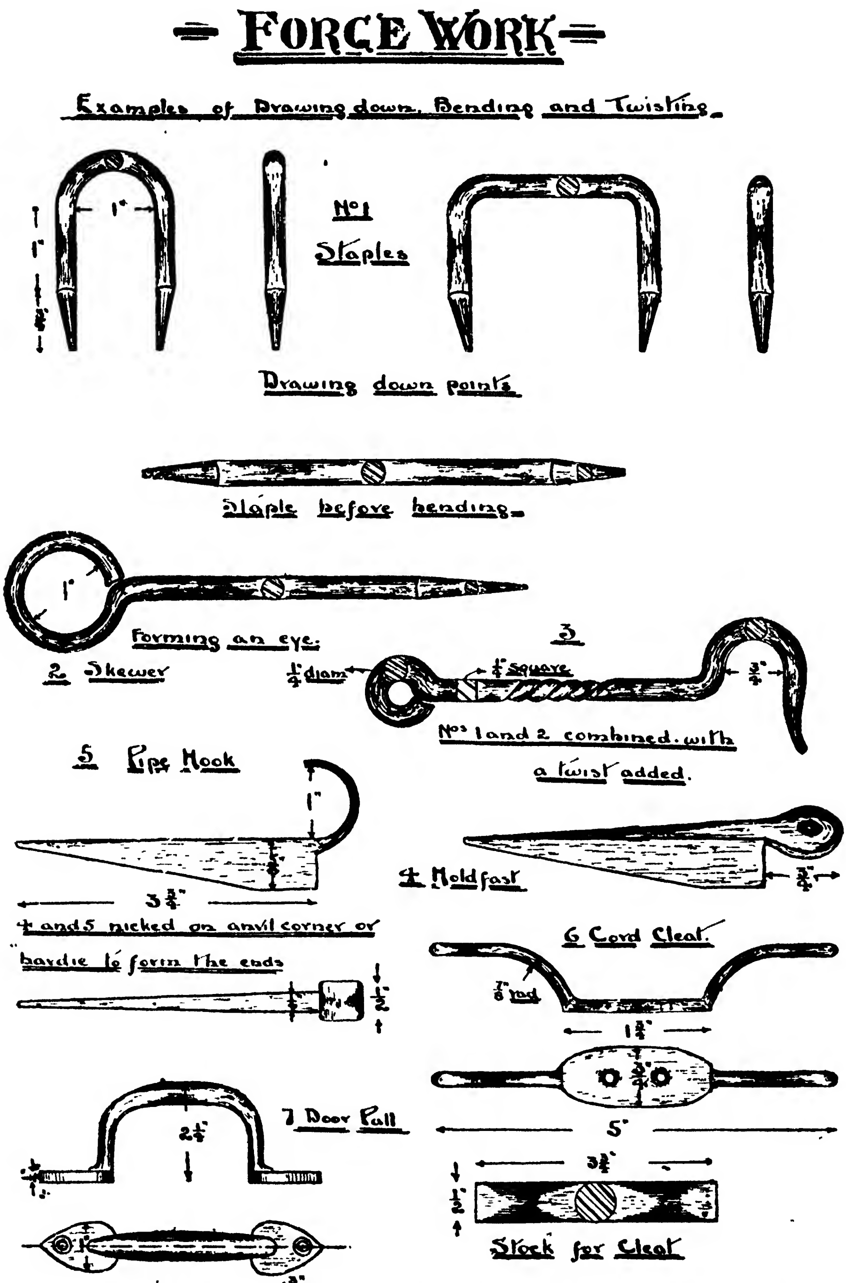


Fig 30 Nos 6 and 7 are drawn down with fullers.

CARE OF FIRE.

For good work the fire must receive constant attention. Before lighting, it must be cleared of fine ash and sulphurous slag; the slice being used for this purpose. New fuel can then be banked up at the back, to be drawn over with the rake as required. The most suitable fuel is coke breeze ordered to the following specification:—

Best smithy breeze, walnut size, to be washed, screened and picked.

The fire should never be allowed to become "thin." Forced draught increases the amount of oxygen which combines with the fuel, causing it to give up its heat units more rapidly than under normal conditions. If there be insufficient fuel to combine with all the oxygen, an excessive amount of scale (iron oxide) is formed on the metal. A smith calls such an oxidising fire a 'thin' fire.

A piece of iron tubing made into a Bunsen burner, and attached to a flexible pipe, which has its other end connected with a gas jet, is a quicker and more satisfactory method of kindling the fire than with a wad of oily waste, or with wood. The device shown in the diagram Fig. 29 is fitted to the fires in the smithy shown in Fig. 27 and gives excellent results. The gas need only be burning about three minutes, for sufficient glowing fuel to be ready to be raked in front of the blast nozzle, and new fuel heaped over it.

ANVILS.

Two types of anvils are illustrated. The bodies are wrought iron forgings with a face of cast steel about $\frac{5}{8}''$ in thickness welded on. The "London" pattern has a block or flat face adjoining the pike and stepped down slightly from the anvil face. Cutting can be done on this face, thereby saving the cast steel surface. An anvil of this type weighing about $1\frac{1}{4}$ cwts. and with a $4''$ face, is a suitable one for a metalwork room.

When mounted on a cast iron stand, see swage block, the face should be $22''$ from the ground.

A swage block and stand is a special form of anvil. The block can be turned to any position required, the grooves in the edges being used for work of various sections, and the holes in the face for bending, heading, punching, etc.

SMALL TOOLS.

Very few hand tools are required for forge work. For a group of four boys it will be necessary to provide the following:—

4 pairs of close mouth tongs, Fig. 29, for holding round, square and thin rectangular stock. The tongs should be about $15''$ in length.

2 pairs of hollow bit tongs, Fig. 29, for holding $\frac{5}{8}''$ and $\frac{1}{2}''$ cold chisels.

2 "Hardies," Fig. 29, the square shanks of which fit into the square hole in the anvil face. The cutting edge nicks the bar all round, after which it can be readily broken off.

1 Flatter, Fig. 29, for smoothing surfaces.

1 pair of small Fullers, for drawing down work similar to that shown at Fig. 30 (Door Handle).

4 Hammers of $1\frac{1}{4}$ or $1\frac{1}{2}$ lbs. weight, two of them being round peen and two cross peen, Fig. 29.

1 Light Sledge Hammer 5 to 7 lbs. in weight.

Other tools such as swages, bolsters, punches, heading tools, etc., can be added as the need arises.

FORGING EXERCISES, Fig. 30.

1. STAPLES.

Material required :—
Wrought iron or mild steel, ¼" diameter.

Method :—
Calculate length of stock.
Draw down square points.
Bend to shape.

2 MAKING AN EYE ON A LINK, SKEWER, ETC.

FIG. 31.

Material required :—
Wrought iron or mild steel, ¼" or ⅜" diameter.

Method :—
Calculate length of stock.
Draw down square point on pike of anvil.
Make round on face of anvil.
Bend the portion for the eye at right angles over the back corner of anvil face, see Figs. 31 and 32.
Form the eye over the pike, Figs. 31-33, and close it with gentle blows as required, working on anvil face.
Judge for symmetry with shank as centre line.

3. HOOKS.

Material required :—
Wrought iron (Best Best) ¼" square.

Method :—
Draw down sufficient to make the hook-end and bend at right angles.
Beginning at the angle-end form the hook, using the cross-peen hammer to keep the corner square at the bend.
On the face of the anvil, make the material for the eye round in section instead of square.
Make the eye
Heat the middle of the shank and quench the ends. The twist can then be made by holding one end in a vise, and with a pair of tongs turning the other through one complete turn (Fig. 33).

4. Pipe Clamps.

Material required :—

Mild steel or wrought iron, $\frac{5}{8}'' \times \frac{1}{4}''$.

Method :—

Nick the edge of the material on a hardie, or the square corner of the anvil. The latter method is the better, as it preserves the continuity of the fibres.

Draw down and hammer out the portion for the head.

Before bending the end, draw down the pointed end, and planish.

Bend to required radius (Forging processes No. 2).

5. Holdfasts.

Material required :—

Mild steel or wrought iron, $\frac{5}{8}'' \times \frac{1}{4}''$.

Method :—

'Upset' the end for the eye before nicking. The exercise is now similar to the one described above.

6. Cord Cleat.

Material required :—

Wrought iron (Treble Best), $4'' \times \frac{1}{2}''$ diameter.

Method :—

Draw down one end to sizes required.

Holding this end in the tongs, hammer out the flat middle portion.

Flatten or "set down" with a flatter or set hammer.

Draw down the other end, and cut off to length.

Bend the ends to required radius.

Drill holes for the screws.

Fig. 32.

7. Drawing Down with Fullers. Garage Door Handle.

Material required :—

Wrought iron (Treble Best) or Mild Steel, $4\frac{1}{2}'' \times 1'' \times \frac{1}{2}''$.

Method :—

With Fullers indent the edges of the stock 1″ from each end. (Forging Processes No. 2).

Draw down the middle portion to the round section required.

Shape the ends, using a set hammer for flattening, and a hand hammer for making heart shape.

Drill holes for the screws.

FORGING PROCESSES.

As will be seen from the drawings, the forgework attempted is not of a heavy character. Such examples as have been selected are capable of being executed by boys of average physique, and provide for progressive experience in the following operations :—

<table>
<tr><td>Drawing down
Upsetting
Bending
Fullering and Swaging
Welding</td><td>These may be described as primary operations</td></tr>
<tr><td>Decorative treatment, e.g.,
    Flaring
    Twisting
Heat treatment, e.g.,
    Annealing
    Hardening
    Tempering
Surface treatment, e.g.,
    Case hardening</td><td>And these as secondary operations.</td></tr>
</table>

Most of the work can be performed single-handed, but assistance is required when it is necessary to use a flatter, or fullers and swages, and when welding the ends of two rods.

It is a natural mistake for students, with no previous experience in the working of metal, to think that if iron is heated to a red heat, it is in a suitable condition to be hammered to any extent. It will be necessary for the teacher to correct this wrong impression by demonstrating the right working "heats," and by brief talks on the properties of the materials being used, linking up whatever science knowledge a boy may have acquired, with the processes of Iron and Steel Manufacture, and the working of these metals in the forge. Wrought iron must be worked at a yellow heat. Any hammering of the metal below the temperature indicated by the glowing yellow colour will cause it to split, especially if it be below the treble best grade in quality.

Mild steel being more homogeneous than wrought iron may be worked at a lower temperature, that is to say, if heated to a yellow heat, it can be hammered vigorously without danger of splitting, as the temperature is much longer in falling than in the case of wrought iron. Because of this it has been found advisable, until students have become accustomed to their new responsibilities, *e.g.*, care of fire, control of blast, use of tongs, timing of blows, etc., to allow them to use mild steel, not introducing wrought iron until after a few weeks' practice has been obtained. Cast or carbon tool steel must be worked at a much lower temperature. The colour should on no account be allowed to go much beyond cherry-red, else the metal will be "burnt," and its structure so altered as to render it useless.

LIST OF FORGING TEMPERATURES.

Material.	Temp. (Fah.) approx.	Colour.	Remarks.
"Wrot" Iron	1850	Yellow	Appearance in average daylight. A heated piece of metal looks brighter on a dull than on a bright day
Mild Steel	1800	Full Bright Red	
Cast Steel, 1% C.	1600	Full Red	

For good work it is very important that the hammer blow should be correctly timed and accurately placed. Tool drill is now looked upon with disfavour, but whatever looseness may be permitted in the handling of some tools, none is possible for well finished hammer work. The time is well occupied if arrangements are made whereby every group of beginners may spend a few minutes actually hammering cold iron, timing each blow by repeating :—one——two——one——two——, etc., and giving the work a turn through 90° by an outward twist between each fall of the hammer.

AMOUNT OF STOCK.

When making a bend, it is assumed that the bending line is the neutral axis of the material, so, to calculate the length of stock required for an eye or link, the mean diameter is the one taken. A student would naturally apply his mathematics, but a smith adopts the rule of thumb method :—Three times inside diameter + four times diameter of metal.

To estimate accurately the length of square or rectangular stock to make a forging of an entirely different shape, the volume of the finished work must be calculated from data given on the drawing. A piece of material having a similar volume can then be cut from the bar.

Lead wire of various diameters is used for determining the length of stock for intricate curves. A full size pattern of the curve is first drawn out and the wire bent to it. When straightened, it forms a measure with which to cut off the iron.

DRAWING DOWN.

This is always carried out on the pike of the anvil. The curved top face acts like a large fuller, squeezing and pushing the plastic metal along the bar towards the end. To make boys appreciate this, let them perform the experiment of pointing one end of a piece of rod on the anvil face, and the other on the pike, and time the two operations. Also measure the piece before and after pointing.

Round points are first drawn down square, after which the corners are rounded off on the anvil face. To attempt to make a point round, straight away, will result in the metal " piping," that is, a hollow point will be formed (see Fig. 35), due to the outside layers of metal being stretched more than the inner ones.

UPSETTING.

This is the opposite of " drawing down " and aims at increasing the cross sectional area of the metal by holding it in tongs and hammering the end whilst hot, the work in this case being, of course, held horizontally. If the rod is of such a length that tongs can be dispensed with, the hot end may be thickened by repeated blows on the anvil face, the rod being kept vertical.

Upsetting or " jumping " is always necessary before welding, and is a preliminary operation to the forming of heads on holdfasts and other similar projects. Whilst it is generally the ends of pieces that are upset, in the case of pins, such as the gudgeon pins in crossheads, and in the pistons of internal combustion engines, which have become worn in the middle, these are thickened by heating, quenching the ends, and applying pressure.

There is always a tendency for pieces to bend when being upset, and they should be straightened as soon as a bend starts, otherwise additional blows will only bend the stock more and produce no thickening, also the temperature should be kept slightly above the forging heat in order to render the metal as plastic as possible, and to prevent the splitting of the fibres.

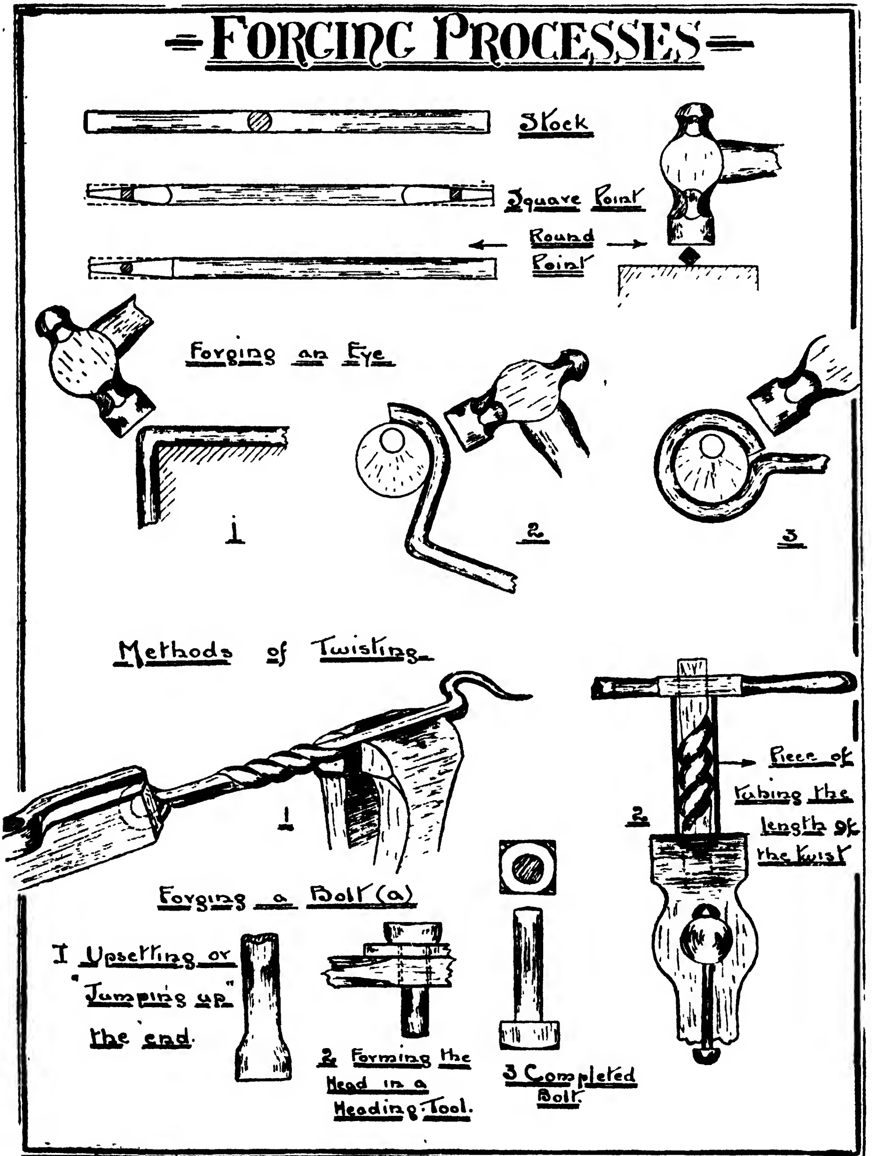


FIG. 33.

BENDING.

Iron of round section is easily bent over the pike or round edge of the anvil. Reasonable care must be taken to avoid damage to the surface by the hammer.

Bending bar iron is more difficult, especially the making of edge-wise bends. The fibres on the convex side of the neutral axis are stretched, while those on the concave side are compressed. The wider the bar, the greater the stresses which tend to wrinkle or buckle the metal. This must be corrected

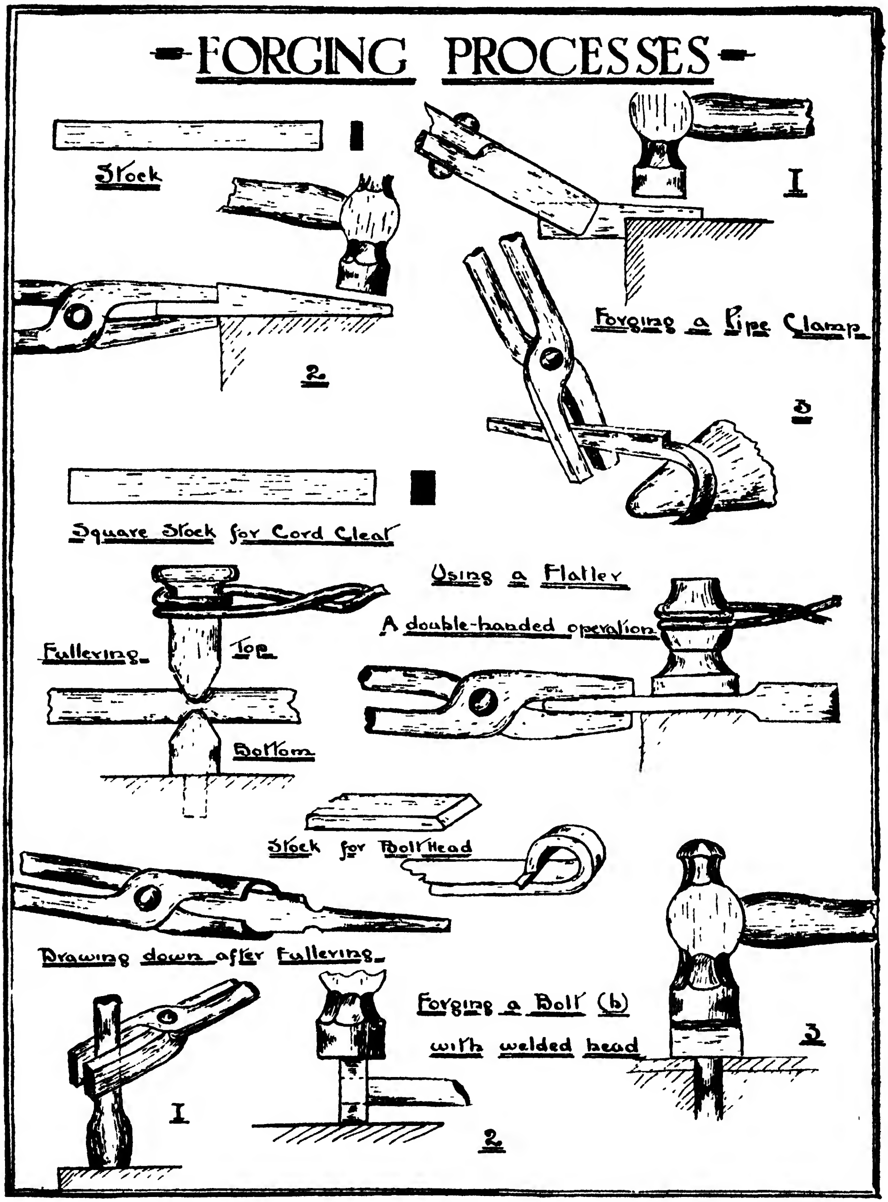


FIG. 34.

by hammer blows on the sides. Flatwise bends are more easily made than edge-wise ones, but it requires a fair degree of skill to forge a good sharp angle in square or rectangular metal.

The processes of making eye bends are illustrated in Fig. 33.

FULLERING.

(Fig. 34). This is the process adopted to change the direction of the fibres without cutting into, and severing them, when it is desired either to reduce the section or to increase the width of a piece of metal. The handle shown in Fig. 30 is a good example. The stock has been increased in width for the heart shaped ends, and drawn down at the right angled bends, but the continuity of the fibres has not been broken, which would have been the case had a sharp edge like a " hardie " been used.

Where the work has only to be fullered on one side as in the pipe clamp, Fig. 34, the square corner of the anvil may be used as shown, but in all work of this kind care must be taken not to indent the material too deeply with sharp edges or the fault illustrated in Fig. 35 will occur. It will be observed that the action of a fuller and that of the pike of an anvil are exactly the same. The convexity of their surfaces causes the metal to be stretched and pushed along the bar, thereby reducing it in section.

Fullers are usually in pairs, the bottom one having a shank which fits in the hole in the anvil face, while the top one is handled like a hammer. When using these tools the top fuller must be held so that it is in the same plane as the bottom one.

SWAGING.

This operation is not carried out to any great extent in the handicraft room. It is the process of finishing work of large diameter to circular form. Like fullers, the swages are in pairs, with either concave or vee shaped interior surfaces. The operation must be carefully performed in order to avoid a drawing down action, and a reduction in the diameter of the bar. Swages of all diameters are about two-thirds of a semi-circle, so the edges of a pair are always well clear when rounding a piece of iron.

FLATTING.

Flat surfaces are finished with " flatters," (Fig. 34), which may be likened to flat swages. Flat faced hammers (set hammers) are also used for setting down square shoulders, and for corners which cannot be worked effectively with ordinary hand hammers.

FLARING AND TWISTING.

These are two of the processes employed in the decorative treatment of wrought iron work when the material is square, rectangular or octagonal in section.

To form a " flare " the end of the metal is hammered down to a thin, not a knife edge, and spread to give it a greater width at the same time. The appearance is improved if the extreme end is made convex with the hammer. The metal is then bent to curved form, such as the feet shown in the examples in Fig. 36a. If special shapes, *e.g.*, heart, trefoil, etc., for the feet of " footman," and similar stands, are required, they must be made by filing before being bent at right angles.

The twist has been adopted by the smith for many centuries as a means of embellishing his handiwork. Very effective in appearance, it is also very easily made.

Two methods of doing this are shown in Fig. 33. The hook is gripped in a vise at the place where the twist should commence, and the free end is then turned through an angle of 180° or 360° with a pair of tongs. The heat should only be sufficient to allow of the metal being twisted readily.

Cold iron can be twisted more evenly than hot, because in the case of the latter the tongs and the vise extract heat from the iron near the places where it is gripped. The hotter portion turns more readily than the cooler part, and the result is an uneven twist.

To form a twist on stout material it may be necessary to use a wrench similar to one used for tapping (Fig. 33), and centre punch marks at each end of the portion to be twisted afford good guidance where to grip the metal.

When a number of similar pieces have to be twisted, the work can be done accurately and quickly by making a sleeve the exact length of the twist, and having an internal diameter slightly larger than the width of the metal. After the work is gripped in the vise, the sleeve is slipped on, the wrench moved down to it and the turn made. The sleeve not only acts as a gauge for the length of twist, but also keeps the bar straight. See Fig. 33.

A bar that is bent during twisting may be straightened with a lead hammer, or between two pieces of wood.

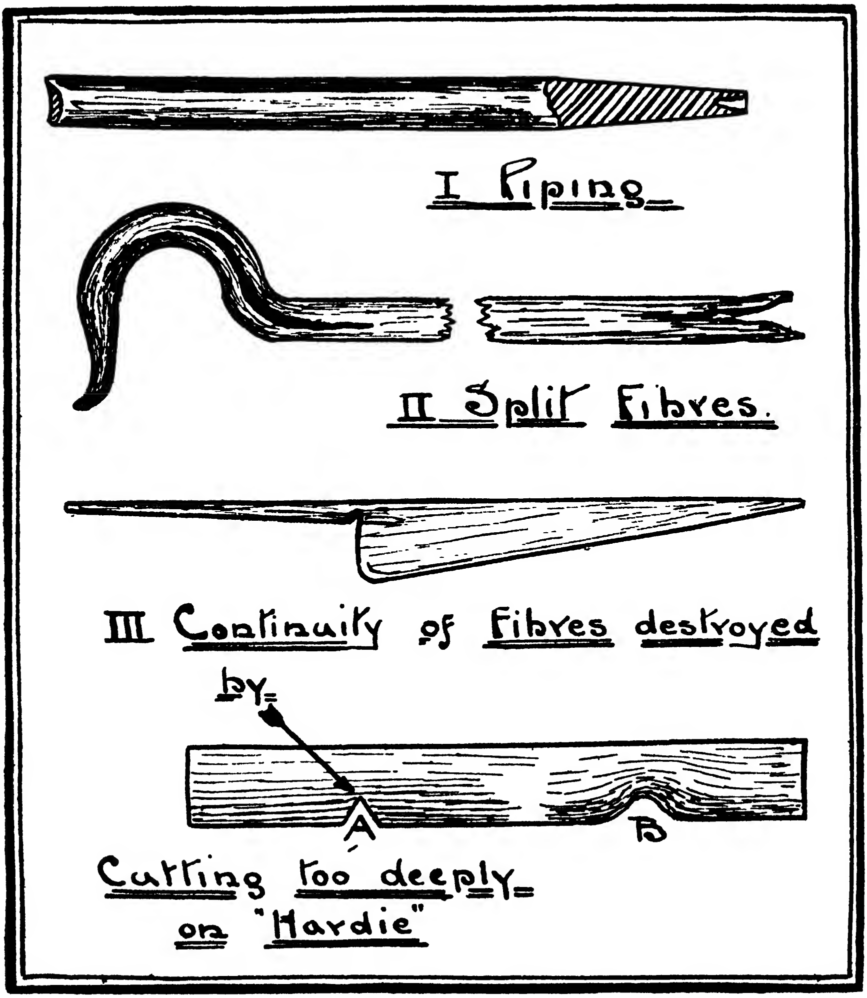


Fig. 35.—Common Faults in "Wrot" Iron Work.

TO AVOID COMMON FAULTS IN WORKING "WROT" IRON.

i. Draw down square before attempting to make a round point.
ii. Work the metal at the correct heat.
iii. Make the indent, as at '*B*,' with a "Fuller" or on a corner of the anvil. The fibres should not be cut through as at '*A*.

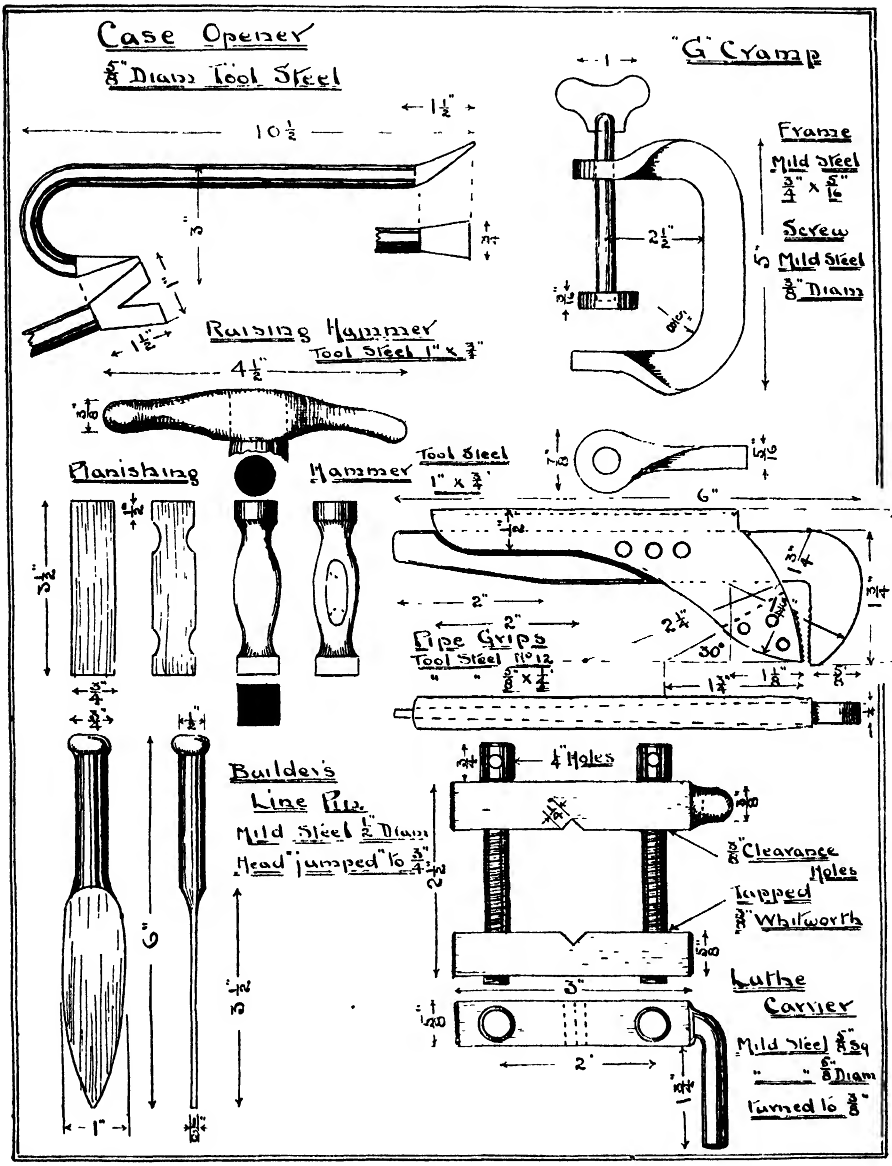


FIG. 36.—TOOLS WITH FORGED PARTS.

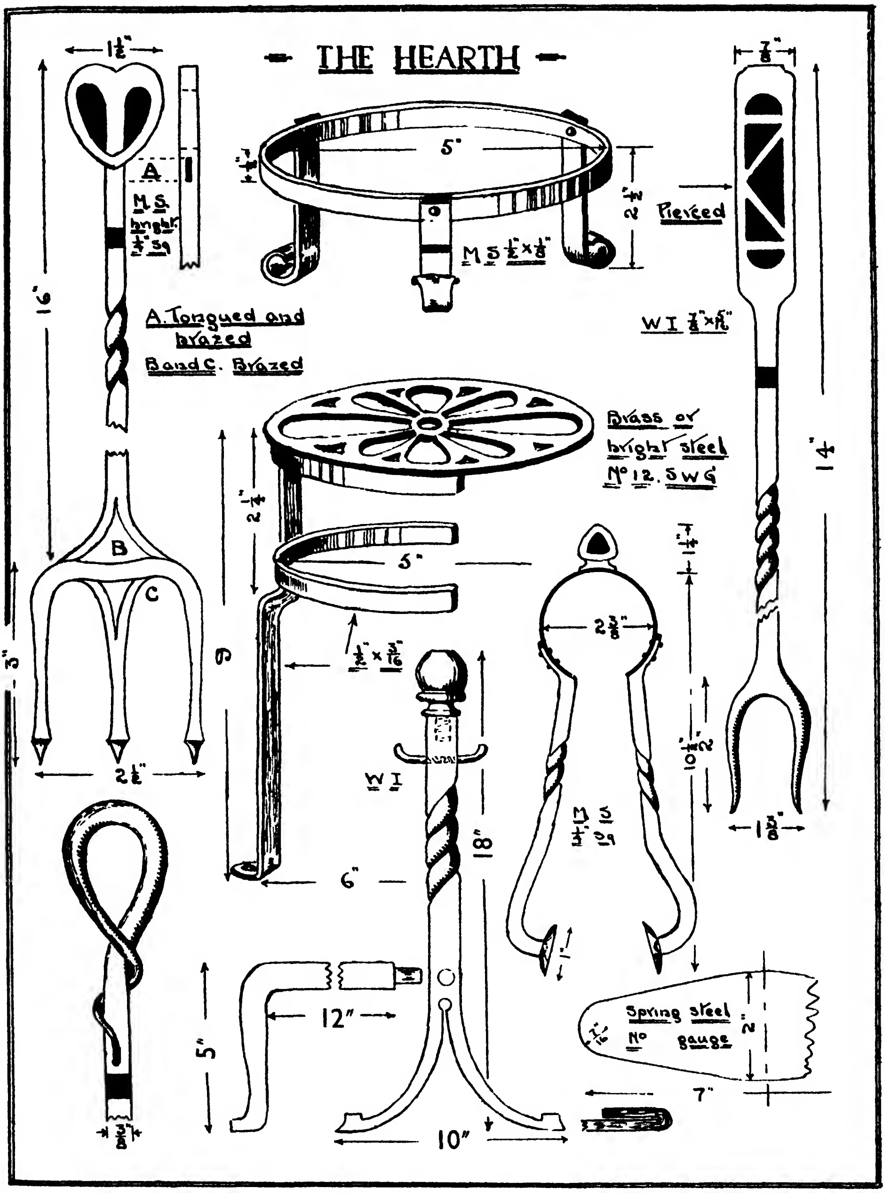


FIG. 36a.
FORGED COMPONENTS.

Forks.
Pokers.
Tongs.

Stands, Trivets, Footmen, Andirons adapted to modern use.

CONSTRUCTIVE WORK.

Exercises involved.

1. Flatwise Bending.
2. Scarfing.
3. Flaring.
4. Rivetting.

All the projects shown in Fig. 36 are made from $\frac{1}{2}'' \times \frac{1}{8}''$ mild steel. The flares are formed on the ends by hammering them out on the pike of the anvil, and planishing on the face before bending. In order to avoid excessive scaling the metal should only be heated to a bright red, as being of small section, it will be found to work quite readily at a low temperature.

When bending the rings, care must be taken to keep the work in one plane. There is always a tendency for it to become distorted and appear " in twist."

The method of joining the ends of the rings is by scarfing and rivetting.

Where legs have to be attached, one should be fixed at the scarfed joint, the rivet passing through the three thicknesses of metal before being rivetted over, and finished with a round head on the outside.

In all work of this kind the rivets should be made a distinctive feature, and this demands a neat finish with a snap tool (see rivetting), not the ugly spread of metal so often seen on hand finished work.

WELDING.

The process of joining iron to iron by hammering, or by pressure, is termed welding. The process consists of heating the parts to be joined, nearly to the point of fusion, and, after bringing them together, uniting them by quick, accurately placed hammer blows, or, in the case of heavy forgings, by squeezing between the anvil and ram of a power hammer.

This joining of semi-fluid pieces of iron and steel by pressure is now thought to be analogous to the freezing together of two pieces of ice when rubbed and subjected to compression, a phenomenon known to physicists as " Regelation." In the case of ice the pressure causes the melting point to be lowered, and a film of water is formed between the two pieces. When the pressure is released the melting point is raised, and the water again freezes and becomes solid.

The exact temperature of the welding heat of iron is not known, but when it is reached the metal becomes pasty or semi-fluid, and when two similarly heated pieces are placed in contact and subjected to pressure, as at the instant of each hammer blow, it is reasonable to assume that the metal liquifies and the particles flow together, the mass becoming solid when the pressure is removed.

Experience is necessary to judge when the welding heat has been reached. At that temperature (about 2,250 Fah.) wrought iron has a dazzling white appearance, and gives off bright sparks of burning iron. If the metal is of large dimensions a hissing noise is heard when it is exposed to the air, due probably to the violent chemical action between the iron and oxygen.

The remarks made previously about the care of the fire, and selection of fuel, must here be emphasised. It is impossible to weld with a dirty or a " thin fire," and the presence of sulphur is fatal to the performance of good work.

FLUXES.

At the welding temperature, the affinity of the metal for oxygen is much greater than at lower ones, and oxide of iron (scale) is formed very rapidly. This scale, whether formed in the fire, or in transit to the anvil, will prevent a weld being made, and chemical means must be taken to dissolve it by the use of fluxes. The fluxes used for smithy work are borax, sand, and sal ammoniac, the latter being mixed with borax. When the iron is approaching

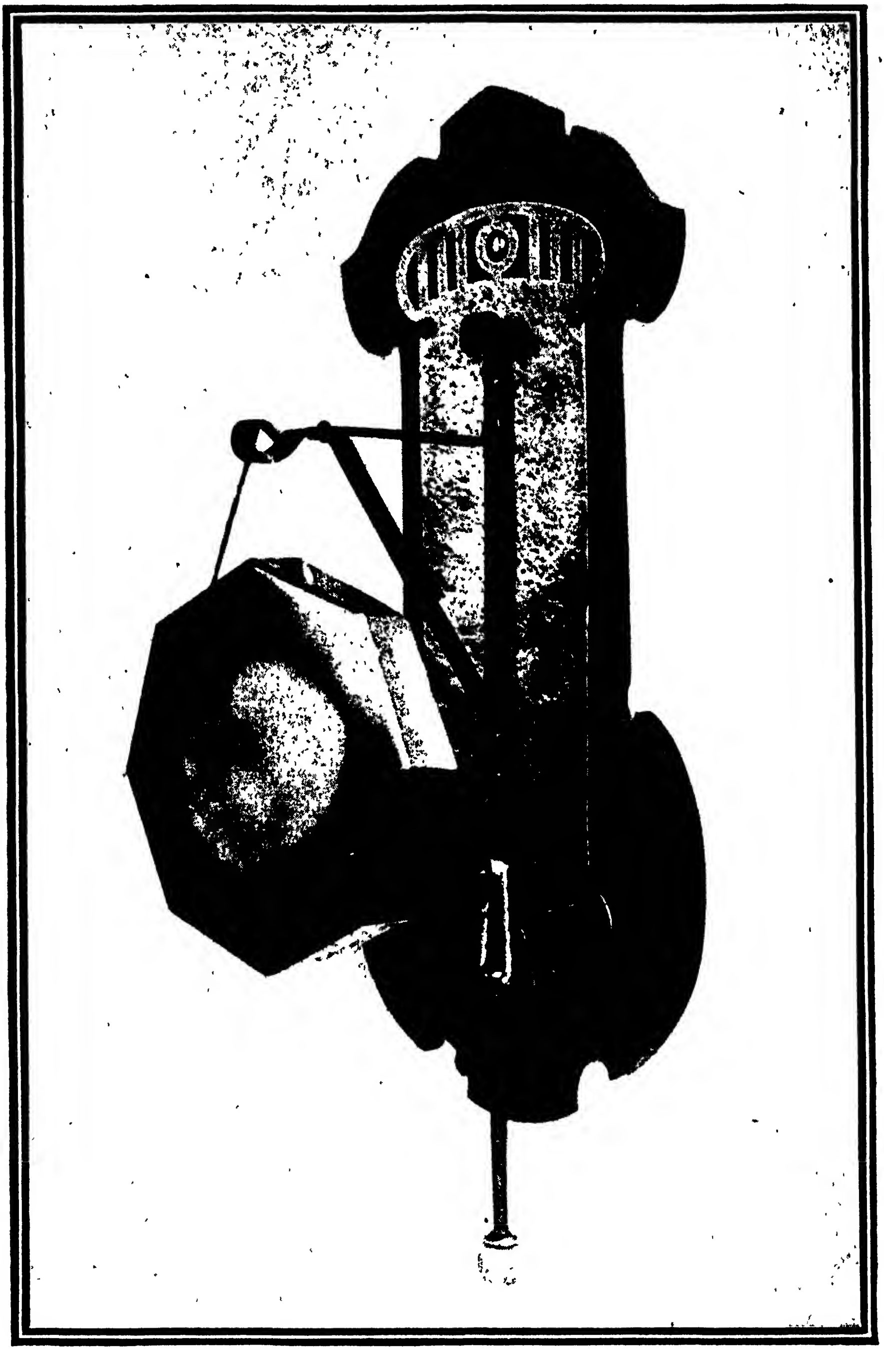


FIG. 37.—BRACKET AND GONG IN WROUGHT IRON AND MILD STEEL.

the requisite heat, a handful of flux is thrown into the fire over the heated ends. The flux melts, and, covering the metal, prevents the further formation of scale, at the same time dissolving that already formed. The outer layers of fibres are also protected from being burnt. By uniting with the oxide, the flux forms a fusible slag, which can be shaken or thrown off the metal when withdrawn from the fire, or forced out of the joint by hammering. Before using borax, the water of crystallisation should be driven off, and the dehydrated borax pulverised in a mortar. The resulting product is a dark coloured powder called borax glass, which, when mixed with sal ammoniac in the proportion of 5 parts borax to 1 part ammonium chloride, makes an excellent flux for all round welding.

WELDING PROCESSES.

The simplest weld to manipulate is the " faggot weld " illustrated in Fig. 38. It forms a good introductory exercise, enabling a student to become familiar with welding heats.

Gib headed keys are frequently made in the manner shown. The head is formed by bending the metal double, and welding solid. If this be done on the end of a long rod, tongs can be dispensed with, and the work becomes comparatively easy, the student being able to give his whole attention to obtaining the correct working temperature.

Another simple weld is the joining of the two ends of a link or ring (Fig. 38). This is a " lap weld " and a single handed job, which is quite within the capacity of handicraft classes. Preparatory to the weld being made, two operations must be carried out, viz., the ends of the stock must be slightly upset or thickened, to allow for wastage and finishing, without reducing the diameter of the metal; then, on the back edge of the anvil, the ends must be hammered down diagonally or scarfed (see Fig. 38).

The face of the scarf should be slightly convex, because, if made concave an air pocket will be formed between the faces of the metal which prevents rapid contact when the ends are brought together.

These preparations having been made, the link can be roughly forged to shape, bringing the scarfed ends overlapping each other and slightly separated.

Care must be taken to heat the iron uniformly and slowly by frequently turning the tongs in the fire. If it be heated too rapidly, the outside will be at the welding temperature whilst the interior is comparatively cold.

When the iron is withdrawn from the fire, any slag adhering to it can be shaken off by giving the tongs a slight tap on the anvil. A sharp blow with the hammer will then unite the two scarfed ends, after which the joint can be neatly finished, and the link formed to the required shape.

A Welded Head Bolt affords good practice, and is an alternative to the ' upset ' method previously described. Comparing the two methods, better proportions are generally obtained when the heads are welded on. The stock (1, Fig. 38) is upset at the end, and a collar of round or square material is made to fit tightly round it as at ' 2.'

In choosing material for the collar, the following sizes of bolt heads in terms of the diameter D should be borne in mind:—

D = Diameter of bolt.

$1\frac{1}{2}D+\frac{1}{8}''$ = Distance across the flats.

$d = D$ = Thickness of the head.

Heat the head slowly to prevent the collar burning, and weld by hammering on all four sides. Forge to the correct sizes, and finish the bolt in a heading tool.

In addition to these common welds there are many others used by smiths, Butt, V, Split, and Angle Welds being but a few of them. They are usually made from heavy stock, and require large fires, heavy tools, and the skill of an expert craftsman for their successful accomplishment.

FORGING TOOL STEEL.

The operations described in the forging of wrought iron and mild steel are identical with those employed by the tool smith in the shaping and forming of steel cutting tools, but, extreme care is necessary when heating the material, and for the successful handling of it, a knowledge of its structure and properties is essential.

Tool Steel, which is also called Cast Steel and Carbon Steel, is an alloy of iron and carbon, the percentage of carbon being very small, varying between 0.5 and 1.5. The carbon is the hardening element in the steel, and to indicate the percentage, steel makers use the term "Temper" and classify steels as follows :—

CLASSIFICATION OF TOOL STEELS.

Steel.	% of Carbon.	Special Properties.	Forging Colour.	Tools made from
Razor Temper	1.5	Cannot be welded	Full cherry red	Special Turning Tools. Surgical Instruments.
Tool Temper	1.25	Not weldable. Can be worked at a heat up to the point at which scale begins to form.	Bright cherry red	Twist drills, Lathe tools. Files.
Die Temper	1.125	Weldable with care	Red	Taps and Dies. Reamers, Milling Cutters.
Chisel Temper	1.00	Can be welded	Full red	Cold chisel Punches Smith's tools.
Set Temper	0.75	Easily welded	Bright red	Hammers. Rock Drills. Tools in which a hard skin with a tough interior is needed.

Another designation which is given to steel is the term "point," a point being .01% of carbon. 50 Point carbon steel is steel with 0.50% of carbon. From this it will be seen that for different requirements various grades of steel are necessary, and it is not sufficient when ordering material for the metalwork room merely to state the quantity required, and leave it to the dealer to select the quality. The purpose for which the steel is needed should be definitely stated on the order, *e.g.*,

CAST STEEL. *x* lbs. ⅝" hexagonal (Chisel Temper) 1% Carbon.
x „ ⅜" diameter (Die Temper) 1.25% Carbon.

The stock should be cut with a hack saw or, while hot, with sets. Cracks are likely to be formed if it is cut cold by nicking round, this defect becoming more apparent when the tool is hardened.

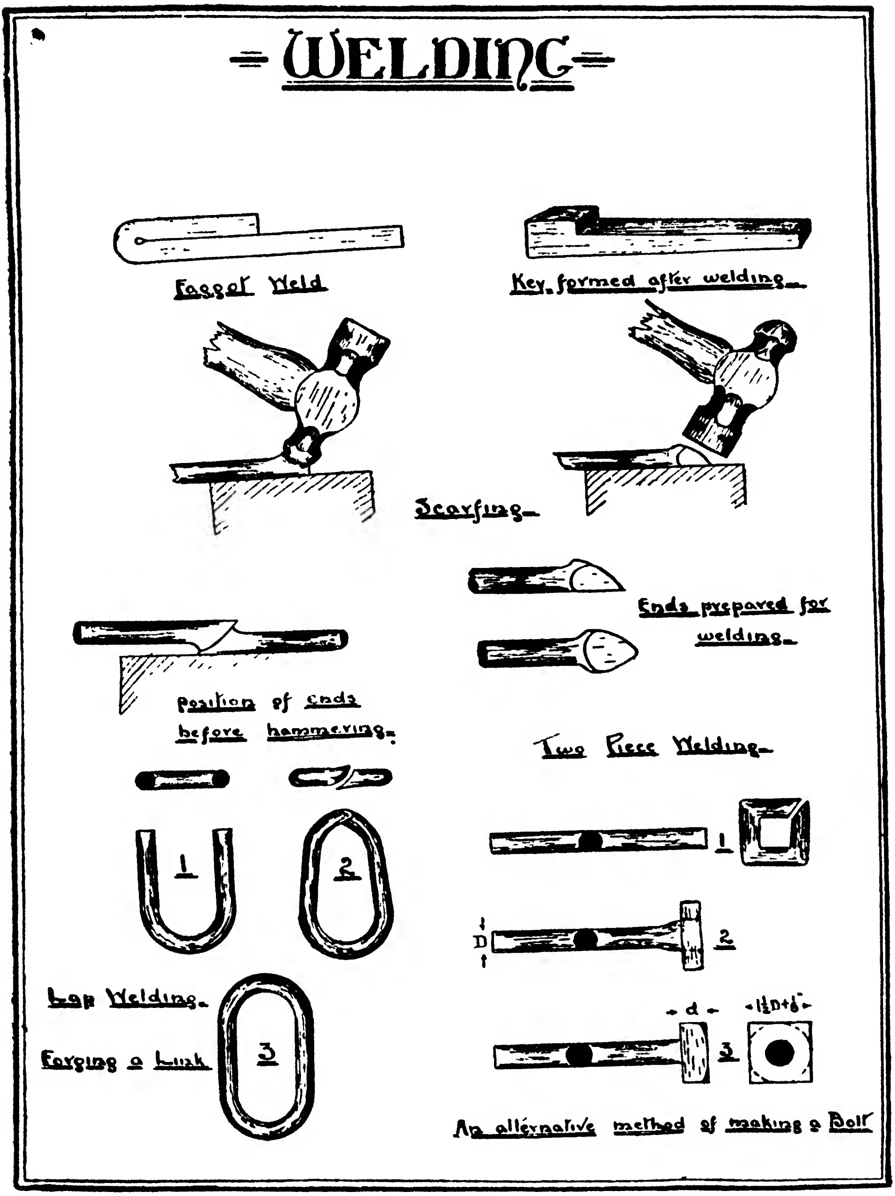


FIG. 38.

HEATING TOOL STEEL.

There is a general idea amongst metal workers that the heat at which tool steel should be forged is a " cherry red." This is rather a vague term, and manufacturers are not agreed as to the temperature it exactly represents, and, apart from the possibility that no two persons see a colour exactly alike, it should be borne in mind that a heated object looks brighter on a dull, than on a bright day.

The colours given in column four of the Table of Steels, are those to which steels of known carbon content should be raised in average daylight for successful forging. The temperatures, as indicated by the colours, should be strictly adhered to, and students should be shown and allowed to perform experiments by heating pieces of steel to different temperatures, in order to make them familiar with the colours that steel assumes, and its variable appearance in different lights.

Steel should never be allowed to remain in the fire longer than is necessary to heat it uniformly throughout. If left to "soak" after the required temperature has been reached, a soft skin will be formed on the tool due to surface decarbonization.

It is important to avoid the blast playing directly on the metal, or the surface exposed will be burnt, and soft places and cracks in hardening will result. The steel should also be well covered with fuel to guard against the surface becoming decarbonised by influence of oxygen in the air. After forging it is advisable to re-heat all tools to a "cherry red," and allow them to cool slowly in lime, ashes, or sand, before grinding or hardening. This relieves the internal stresses set up during the hammering, and is termed "normalising." The risk of distortion and cracking during hardening is greatly diminished, and the tool is in a softer condition for grinding. It is a sound rule never to harden a tool during the forging heat, but allow to cool and then to heat it up for further heat treatment.

When forging cutting tools, *e.g.*, chisels, lathe tools, knife edges, etc., an old couplet quoted by smiths should be borne in mind :—

"He that will a good edge win
Must forge thick and grind thin."

From what has been said before, the underlying truth of this is apparent. Frequent heating causes the metal to decarbonise and a soft skin to form on the surface ; but if the tool end is left thick enough, grinding removes this skin, leaving sound homogeneous material on which to make an edge.

EXERCISES.

1. Nail Punch.

Material required :—

$\frac{3}{8}''$ diam. steel.

Method :—

Measure and cut off stock.
Draw down at full red heat.
Grind on the side of emery wheel, and chamfer the top end.
Harden and temper.

2. Centre Punch.

Material required :—

$\frac{3}{8}''$ or $\frac{1}{2}''$ hexagonal steel.

Method :—

Shape the top end.
Draw the pointed end down roughly to shape.
Grind both ends on the side of emery wheel to true conical shape.
Harden and temper.
Grind the point on wet stone and finish bright.

3. SCRIBER.

Material required :—

$\frac{3}{16}''$ square steel.

Method :—

Draw down the top end to thin rectangular section.

Holding this end in tongs draw down the point.

Form the twist.

Grind the point either square or round, and brighten the rectangular portion.

Heat the top end to redness in a blowpipe flame, and with large round nosed pliers, bend as at '*A*,' Fig. 39.

Harden, temper, and polish.

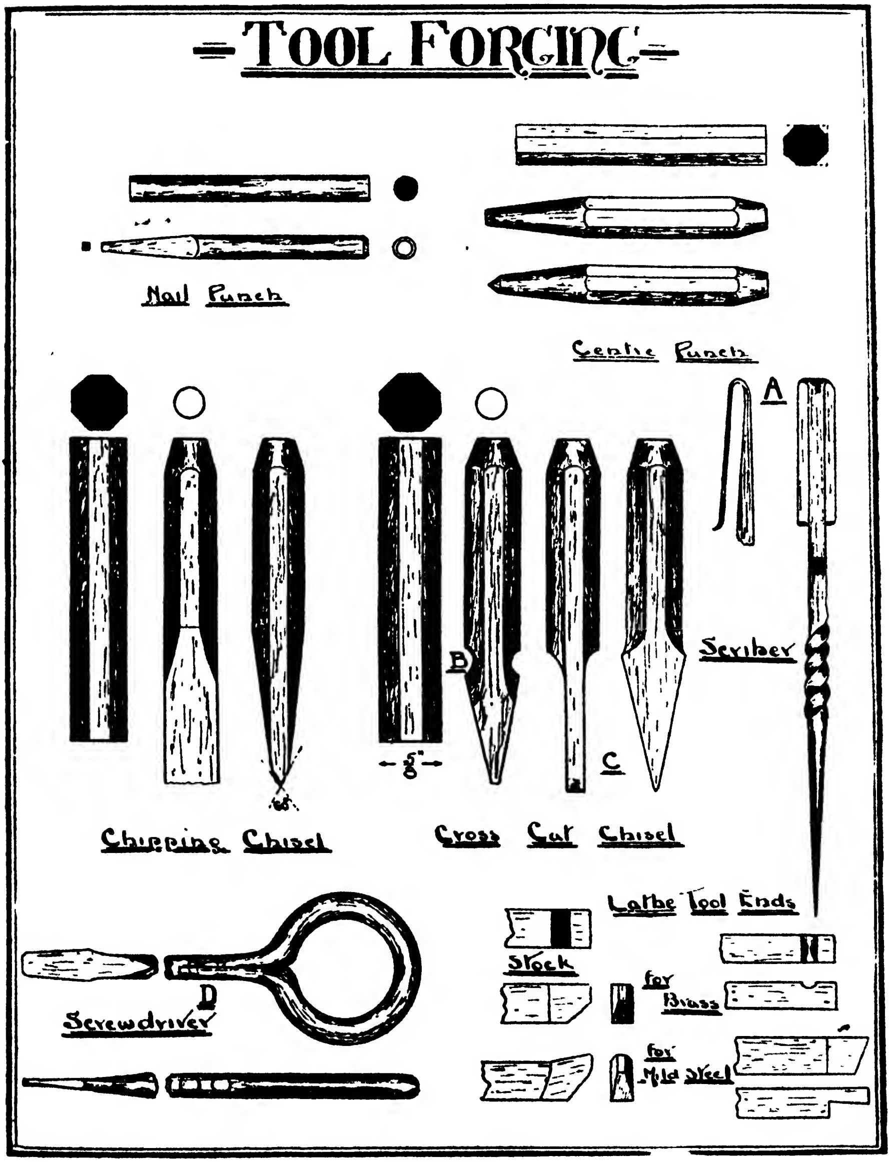


FIG. 39.

4. CHIPPING CHISEL.

Material required :—
$\frac{1}{2}''$ or $\frac{5}{8}''$ hexagonal steel.

Method :—
Heat the head end to a bright red, and taper.
Draw down the cutting end, and finish with a flatter.
Allow to cool slowly to relieve internal stresses.
Grind to shape and to remove outside skin.
Harden and temper (reddy blue).
Finally grind the edge to an angle of 60°.

NOTE.—Do not hammer the material when black.

5. CROSS-CUT OR CAPE CHISEL.

Material required :—
$\frac{1}{2}''$ or $\frac{5}{8}''$ hexagonal steel.

Method :—
Taper the head end.
Draw down the cutting end, making it square in section.
Fuller two sides, 2″ from the end, with $\frac{1}{2}''$ top and bottom fullers, see '*B*,' Fig. 39.
On the horn of the anvil draw down and flatten the end, shaping it like '*C*,' Fig. 39.
Finish with a flatter.
Harden, temper, and grind in the same manner as for the flat chisel.

NOTE.—Avoid making the indents with the fullers too deep, or the blade will be too thin.

6. SCREWDRIVER.

Material required :—
$\frac{3}{8}''$ diam. round steel.

Method :—
Calculate length and cut off the necessary amount of $\frac{3}{8}''$ diameter steel.
Form the ring, taking care to allow sufficient material for rivetting.
Bend the overlap down the shank and mark the position of the end of the shank.
Slightly open the eye and file away material to form the butt joint '*D*,' Fig. 39.
Drill, countersink, and rivet up the joint.
Draw down the driver end.
Grind, harden, and temper (Dark Brown to purple).

NOTE.—The handle may be improved by elongating, the steel flattened, and pieces of hardwood put on each side. These pieces may be screwed together through the eye, and modelled to shape with rasps and files.

7. Lathe Tool Ends.

Method :—

The sketches suggest the processes for shaping these on the ends of rectangular stock.

The parting tool is much easier to make when the blade is flush with one side.

When tempering, the colour should be between light yellow and straw.

Note.—High Speed Steel is superior for this purpose. Very little forging is required, the necessary tool angles being formed by the fitting of the tool holder.

HIGH SPEED STEEL.

Metallurgical science has, during recent years, introduced many new steel alloys which have some remarkable properties, the chief being that of self hardening.

The term High Speed Steel is applied to these alloys, because tools made from them are capable of taking very heavy cuts at rapid speeds without the cutting edges being impaired, although the temperature rises to such an extent that they become almost red hot.

Mushet Steel, which can be bought by the pound, in sections from ¼″ square upwards, is an alloy of steel and tungsten. It is sold in an annealed state, and short pieces may be cut from the bar, roughly forged to shape, ground, and finally hardened, before being fitted into tool holders for use. The actual amount of steel required is very small, a piece 2″ long × ¼″ square will withstand almost daily use in a metalwork room for three months when used as a lathe tool. The forging of these steels should be performed at a bright yellow heat (note the difference from ordinary Carbon Tool Steel), but the metal should be heated up gradually. After shaping, the tool should be allowed to cool in lime or ashes before grinding is attempted.

Tool ends should be ground to shape on an emery wheel before hardening, and on a wet grindstone afterwards for a keen edge.

Hardening is effected by bringing the steel to a dazzling white heat and cooling it in an air blast.

Chromium, Vanadium, and Nickel Steels are other members of this new group of valuable metals brought to the service of the engineer. Many of them have trade names given to them by the makers.

As most high speed steels require special treatment in order to obtain the best results, it is usual for manufacturers to send out instructions with each brand of metal.

The following information was supplied with a consignment of Mushet steel :—

INSTRUCTIONS FOR TREATMENT.

To cut, heat bar thoroughly red, nick on two or more sides, and when cold break in ordinary way. Never break cold without nicking by emery wheel, unless bar is annealed.

Never subject the steel at once to intense heat, but heat slowly to blood red, then quickly up to full yellow—say 1,000° Centigrade, or 1,830° Fahrenheit. (Avoid working below a bright red heat). When shaped ready for hardening, heat nose of tool to nearly welding heat, and immediately cool in cold blast until cold. If air blast not available, quench in thin oil or kerosene (care being taken to keep the oil cool). See that the tool is kept moving until it is quite cold.

GRIND WELL BEFORE USE. WHILST HOT, THE STEEL MUST BE KEPT FROM WATER.

BOOKS FOR REFERENCE.

"Forging of Iron and Steel," W. A. Richards. (Messrs. Constable & Co., Ltd.).

"Elementary Forge Practice," R. H. Harcourt. (Manual Art Press).

"Elementary Forge Practice," J. L. Bacon. (Chapman and Hall).

"Elementary Wrought Iron," Bollinger.

CHAPTER IX.

The Heat Treatment of Steel.

HARDENING. TEMPERING. CASE-HARDENING.

GREAT changes have taken place in the laboratory and the factory since a 16th century writer, steeped in the superstition of the age, published the following instructions for the hardening of iron :—

> " Take snayles and first drawn water of a red die, of which water, being taken in the first month of harvest when it raynes, boil it with the snayles, then heat your iron red hot and quench it therein, and it shall be as hard as steel. Ye may do the like with the blood of a man of XXX years of age and of a sanguine complexion, being of a merry nature and pleasant."

We know iron is incapable of being hardened by heating it to redness and quenching. The only metal possessing this remarkable property is the alloy of iron and carbon, known as carbon steel to differentiate it from mild steel. The percentage of carbon in the alloy is very small, viz., between 0.5 and 1.5, but the hardening property imparted to the metal is due entirely to its presence.

For centuries metal workers have been aware of the fact that great changes in the condition of metals, and of steel in particular, could be brought about by heating and cooling quickly, as by quenching in water, or cooling slowly in air, lime, ashes, sawdust, or some other medium to exclude the air, and they merit our admiration for the excellent results obtained with their limited scientific knowledge, and crude apparatus. Old writings and records, like that of our 16th century metallurgist, make it evident that these early craftsmen attached much more importance to the liquid, in which the steel should be quenched, if it was to be successfully hardened, than to the temperature from which such quenching should take place.

HARDENING.

In Chapter VIII. it is stated that cast steel tools, after being forged to shape, should be allowed to cool out slowly. They are then in a soft annealed condition, or " normalised." Hardening is the next process, and in re-heating the tool, the greatest care is needed, because the grain of the steel varies with slight changes of temperature, and, as it is desirable to have as fine a grain as possible for an efficient tool, only a sufficient amount of heat to produce it must be introduced into the material.

DECALESCENCE AND RECALESCENCE.

When cast steel is heated and tested with a pyrometer, the heat curve shows a steady rise until the neighbourhood of 740°C. is reached. About this point (dependent on the grade of steel) the instrument records a slight drop in temperature, even though the supply of heat is not diminished (see Fig. 40a). Metallurgists call this the " point of decalescence," and the phenomenon is

due to a change which takes place in the carbon at this temperature. When the steel is in the soft annealed state, the carbon exists in the form of a carbide of iron (pearlite). At the decalescent point the carbide is dissolved and remains so at higher temperatures, with an accompanying change in the atomic structure of the metal. In this form it is known as cementite or hardening carbon, and if the steel be suddenly quenched, the dissolved carbide will be fixed in the cementite state.

It is interesting to note that if steel, which has been heated beyond the decalescent point, is allowed to cool slowly, the heat curve falls gradually to about 50° Fah. below decalescence, when it makes a momentary rise; the metal reglows, and increases slightly in volume, after which the curve continues to fall (Fig. 40a).

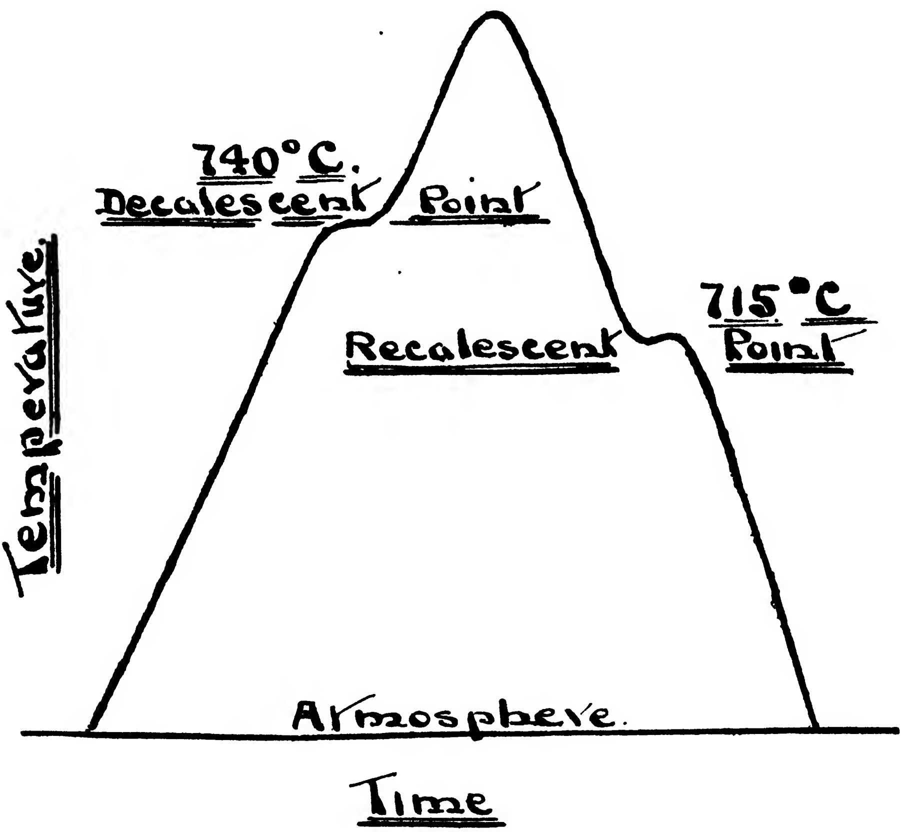


FIG. 40a.—STEEL TEMPERATURE CURVES.

The carbide of iron has changed back again from cementite to pearlite and, providing overheating has not taken place, the steel will be in its original condition.

The temperature at which the falling change takes place is called the "recalescent point." Why it should be 50° or so lower than the ascending change has not been satisfactorily explained.

Steel quenched at the decalescent point has the finest grain it is possible to produce, viz., a grain which has the appearance of fine grey silk. The crystalline particles are of minimum size, and the metal is extremely hard. In this state tool makers call it refined steel, and the temperature to which it has been raised, the refining heat.

The changes produced in the nature of the carbon, and the granular structure of the steel, are graphically represented in Fig. 40b, the particles being shown as squares.

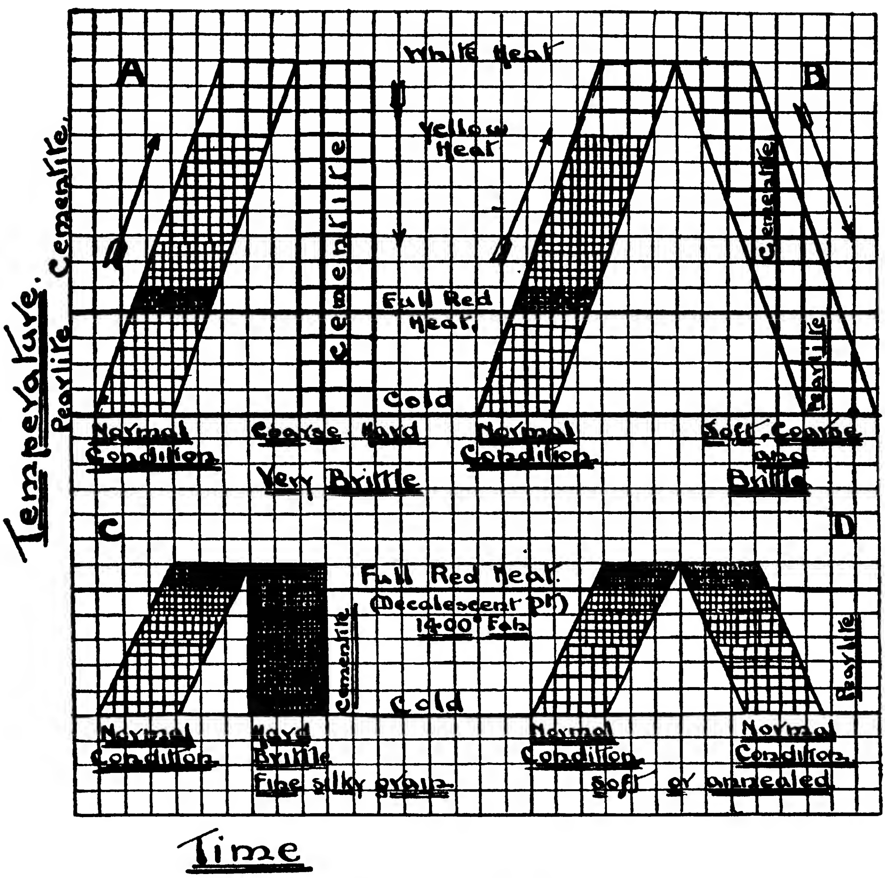


FIG. 40b. GRAPHICAL REPRESENTATION OF CHANGES IN CAST STEEL UNDER HEAT TREATMENT.

It will be seen that in '*A*,' '*B*,' and '*C*' the grains of steel remain the same size up to the decalescent point. At this temperature they become very small, only to increase rapidly in size as the heat is increased. The sudden change in the carbide of iron from pearlite to cementite is also shown in the three diagrams.

If the piece of steel represented by '*A*' is suddenly quenched from the white heat, the grain will be very coarse, each particle remaining the size it was before quenching, but the cementite or hardening carbon will remain fixed. The steel will be very hard, very coarse, and very brittle.

With the piece '*B*,' which is shown cooled gradually, no change has taken place in the size of the particles, which are much larger than in the original bar. But, whilst there is no physical change, there is a chemical one, viz., the cementite changing to the pearlite form at the recalescent point. The steel will be soft, coarse, and brittle. Thus it will be seen that the overheating of cast steel permanently injures the material, and from a tool-making point of view renders it worthless.

Diagram '*C*' shows what takes place when a bar is heated to the decalescent point and suddenly quenched. At the full red heat the grain becomes very fine, and there is a change in the carbide of iron from the soft to the hardening form. The metal remains in this state both physically and chemically if suddenly quenched, when it will be in the best structural condition for tempering or toughening.

'*D*' shows the effect of heating a hardened steel rod and allowing it to cool, in order to anneal it, so that it may be machined or filed. When cool, the particles will have increased in size to those of the original bar, and the carbide will be in the pearlite form again.

HARDENING STEEL IN THE METALWORK ROOM.

It is impossible in the handicraft room to determine the hardening temperature with the accuracy of a pyrometer, but its importance having been demonstrated, more rough and ready methods may be adopted, which give results approximating closely to those obtained by more scientific means. Somewhere about the decalescent point, cast steel is of a bright or cherry red colour, and it may be accepted as a fairly safe rule to heat the metal to a full red colour (not above) and quench in tepid water, in order to produce a steel in a suitable condition for ordinary requirements.

As a demonstration at the end of this important lesson to a class, the following experiment might be performed :—

I. Draw down two or three ends on the cast steel rods.

II. Heat to varying degrees of redness, and note the colour.

III. After quenching, break pieces of the ends and compare the textures of the fractures through a pocket lens.

The colour which produces the finest grain, is the one to which the steel should be heated when tools are being made from that bar.

HARDENING BATHS.

After the steel has been heated to the proper temperature, it must be quenched in water or in a special solution. The more rapidly heat is conducted away from the metal the harder will be the steel, hence, cold water will produce a harder steel than warm, but it must be remembered that too rapid cooling is the most prolific cause of surface cracks. The outside of the steel becomes rigid before the interior, and internal stresses are set up in the material. Tepid water raised to about 60° Fah. makes a suitable and convenient bath for both hardening and tempering.

Other cooling baths consist of saturated solutions of common salt, or sal-ammoniac. The admixture of these salts increases the heat absorbing and hardening effects of the water. Scrapers and hand turning tools, for finishing brass and steel, will give good cutting results, if quenched in one of these baths during the hardening and tempering processes.

On the other hand, if a thick layer of oil or solid grease is allowed to cover the water, the heat absorbing power and hardening effects are diminished. Many small cutting tools are hardened in this way; the tool in its passage through the grease becomes covered with a layer of molten fat, with the result that cooling is retarded, and a tough steel free from cracks is produced.

Petroleum, lard oil, sperm oil, and melted tallow are all used by tool makers for this purpose.

FIG. 41a.—TEMPERING BY METHOD I.

TEMPERING.

Tool steel that has been hardened or " refined " is too brittle for cutting edges on the tools made from it to stand up to their work. A certain quantity of heat must be re-introduced into the steel to toughen or make it less hard. This process of reheating and immersing quickly in a cooling liquid is known as " tempering."

The reheating may be accomplished by one of the following methods :—

I. Directly, by heating in a fire or a Bunsen flame.

II. By placing the cast steel articles on red-hot plates, and heating them by conduction.

III. By immersion in a bath of molten alloy, the melting temperature being just below that required for the tempering process.

Methods I. and II. are the only ones possible in the handicraft room. The temperature can only be estimated approximately, but quite successful results can be obtained with such tools as cold chisels, punches, scribers, screw-drivers, etc., although it is often necessary to re-temper after a first trial. The temperature is indicated by the colour of the film of oxide which forms on the surface of the heated steel. For each temperature the film assumes a definite colour, and reference to the Tempering Chart in Fig. 41 shows that the range extends from a pale lemon colour, denoting a temperature of 420° Fah., to a dark blue, when it reaches approximately 600° Fah.

This change in colour is explained by the super-imposing of film upon film as the temperature increases—a thickening of the oxide layer—but, in order that the colours may be distinctly seen, and so form a reliable guide, it is necessary for the surface of the steel to be ground quite clean and bright.

With the knowledge of these two facts, viz., that the hardness of cast steel varies with the temperature, and that the colour of the oxide also varies with the temperature, it is not difficult to make a temperature chart, similar to that shown in Fig. 41, to hang in a convenient position in the metalwork room for reference.

Fig. 41a shows a piece of hardened cast steel, in this case a chipping chisel, being reheated in a blow-pipe flame. The heat is introduced just behind the brightened surfaces, and when the temperature reaches 420° approximately, a narrow band of pale straw-colour will appear across the metal : this will be followed quickly by bands of dark straw, light and dark browns, reddish blue or purple, and finally blue.

As the volume of the metal becomes less, the colours will travel more rapidly, and when the right colour (purple for chisels) reaches the end, the quick immersion of the tool will retain or " fix " the material in a toughened or tempered condition.

POINT HARDENING AND TEMPERING.

Such tools as cold chisels, centre punches, etc., are frequently hardened and tempered in one operation. When the tool has been forged and ground to shape, it is heated to redness for about half its length, and then dipped vertically to about 2″ from the end, in tepid water, until cold. A slight movement should be given to the tool, to counteract any tendency to crack at the water line, and also to allow any steam formed, to escape from the steel surface. The tool will now be black at both ends, and red in middle. The shank is a reservoir of heat for reheating the hardened end, and if the cooled portion is polished with a piece of sandstone, or an emery stick, to remove the black oxide, the tempering colours will be readily seen. When the desired colour reaches the end, the tool is finally quenched.

There is a tendency with students to leave too much heat in the tool shank, with the result that the colours run too fast, and are too close together for an accurate determination of any particular one.

TREATMENT OF HIGH SPEED STEELS.

The increased use of these new steels for tools and cutters, introduces problems not met with before in hardening and tempering processes.

Of the many fallacies concerning these alloys the two commonest are :—(i.) that they cannot be hardened in water, and (ii.) that they cannot be overheated. Both ideas are quite erroneous, as anyone can easily demonstrate for himself. When cutting, the edge of an ordinary carbon steel tool should never be allowed to reach the temperature to which it has been raised for tempering. If it is permitted to do so, by too high a cutting speed, the tool will be further tempered and softened. But if a small proportion of tungsten, chromium, manganese, or nickel, be added to the alloy, tools made from it may be made to cut at a much higher rate of speed, with the consequent raising of temperature, without the cutting edges becoming softened, and because of this very useful property the material is called High Speed Steel.

As the elements mentioned only affect the steel in the presence of carbon, their special function seems to be to prevent it separating out in the form of carbide of iron. In other words high speed steel is a special kind of tool steel containing other elements, whose effect is to raise the decalescent point to a much higher temperature than that for ordinary carbon steel, but if that temperature be exceeded, the grain of the metal will become coarse, and the same results of overheating shown by the diagram in Fig. 40b will again be evident.

All high speed steels are brittle, and too rapid cooling should be avoided or cracking will occur. Air blast, or oil baths (paraffin) are the best cooling agents.

Makers of these steels usually issue instructions with the brands they supply (see page 86), and these should be strictly adhered to, when heating and cooling.

CASE-HARDENING.

The process of case-hardening may be applied to many small tools, such as spanners, tap wrenches, etc., sometimes made as metal working exercises.

Screws and bolts, as for instance those used in the tool posts of lathes, or the tool holders of shaping machines, should be case-hardened to prevent the ends from spreading, and the heads from wearing, under the frequent stresses exerted by the use of spanners upon them.

The process consists of forming a skin or casing of high carbon steel on wrought iron or mild steel.

Owing to the small amount of carbon contained in mild steel (not more than 0.25%) it is not possible to harden it, but by means of the case-hardening process more carbon may be added, imparting to the surface all the hardening properties of cast steel.

The simplest method, and the only one possible in the metalwork room, is the ferro-cyanide process.

Potassium ferro-cyanide $K_4Fe(CN)_6$, (yellow prussiate of potash) is crushed and placed in an iron pan, where it can be kept permanently.

The articles to be treated are heated and brought to a bright red colour, when they are rolled in the powder. The cyanide fuses and covers the metal, which is again raised to a red heat, and then plunged into cold water

The hardened skin obtained by this process is of course very thin, rarely exceeding $^1/_{32}''$ in thickness.

Immersing in a bath of molten cyanide will give more uniform results, but great care is necessary in the handling of this chemical, as the fumes from it are very deadly. When using it, the pan should be placed under the hood of the forge fire, in order that any gases generated may be carried away, and not dispersed about the room.

Many of the parts of cycles, typewriters, sewing machines, small arms, etc., are case-hardened, and when these are treated in bulk, the articles are placed in a cast iron box surrounded by some carbonaceous substances such as carbonised leather, bones, or powdered charcoal. When the box is full, a close fitting lid is placed on top, and sealed with a luting of clay. The box and contents are then heated in a furnace to a bright red, and are kept at an even temperature for a period varying between two and twenty-four hours, after which they are plunged into water.

The time allowed for carbonisation depends upon the depth of casing required, and the carbonising substance used.

It is possible by this method to case-harden mild steel to a depth of ⅛th of an inch.

There are now several patent preparations on the market for case-hardening, which, if used carefully in accordance with instructions, are very reliable in their action.

THE ANNEALING OF METALS.

When metals are hammered, as in the raising of copper and brass ; rolled, as in the manufacture of plates and sheets ; or stretched, as in wire-drawing, they become less malleable.

> NOTE.—Some metals are malleable when hot but not when cold. They are then said to be cold-short. The presence of phosphorus in iron affects the metal in this way. Other metals are just the reverse and are termed hot-short. Sulphur is conducive to hot-shortness in iron and steel.

Malleability depends on softness and toughness, and when metals are stressed in any of the ways stated, their molecules are forced into unnatural positions, and hardness, even to the point of brittleness, may be the result.

The process of restoring the molecules to their original position, and the metal to its normal state, is known as annealing.

In every case the metal is heated, but the subsequent treatment varies.

ANNEALING PROCESSES.

Copper	Heat to redness, and quench in water.
Brass	Heat to redness and allow to cool slowly. If quenched suddenly there is a danger of cracking, especially at corners.
Zinc	Heat to about 200° Fah. by immersing in hot water. Zinc works better, and is more malleable at this temperature than at any other.

Aluminium	..	Rub with soap, and heat over a stove or fire until the soap turns black.
Cast Steel	..	Heat to a cherry red, and allow to cool out of contact with the air.
		NOTE.—The hardness of cast steel is due to other causes than internal stress. See Hardening and Tempering.

The theory of annealing will be readily understood by a study of the structure of matter, its discontinuity, and electrical components.

BOOKS FOR REFERENCE.

Concerning the Nature of Things—Sir Wm. Bragg.

Steel and Iron—Wm. H. Greenwood.

Principles of Metallurgy—Arthur H. Hiorns.

CHAPTER X.

Sheet and Plate Metal Work.

IT is the rule rather than the exception now-a-days, to find in every well-conducted handicraft room, where woodwork is the chief occupation, some provision made for working in sheet metal. The materials, usually tinplate, thin copper, brass, aluminium, and zinc, are introduced not as substitutes for timber, but as a means of embellishing, strengthening, and completing projects, which, would otherwise be lacking in that fitness for use, which must be the first essential of a piece of handicraft.

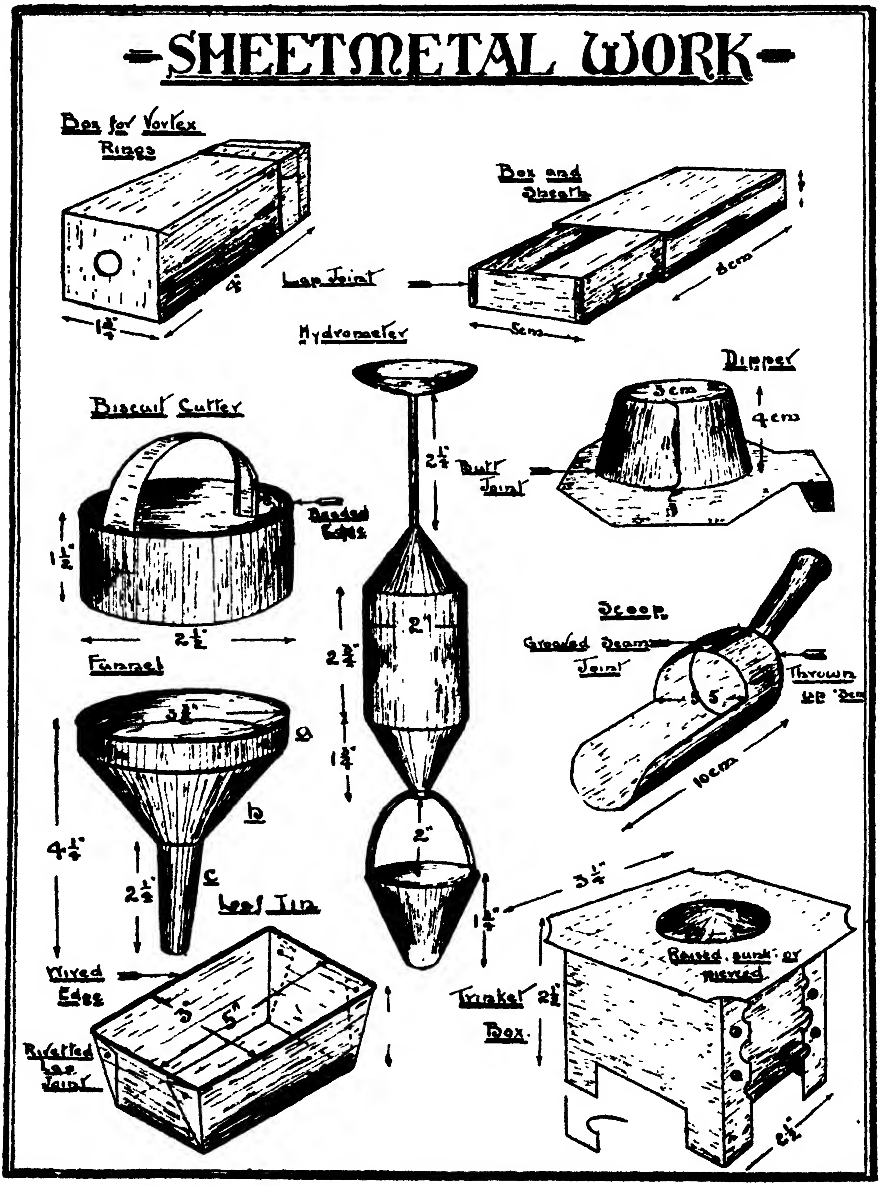
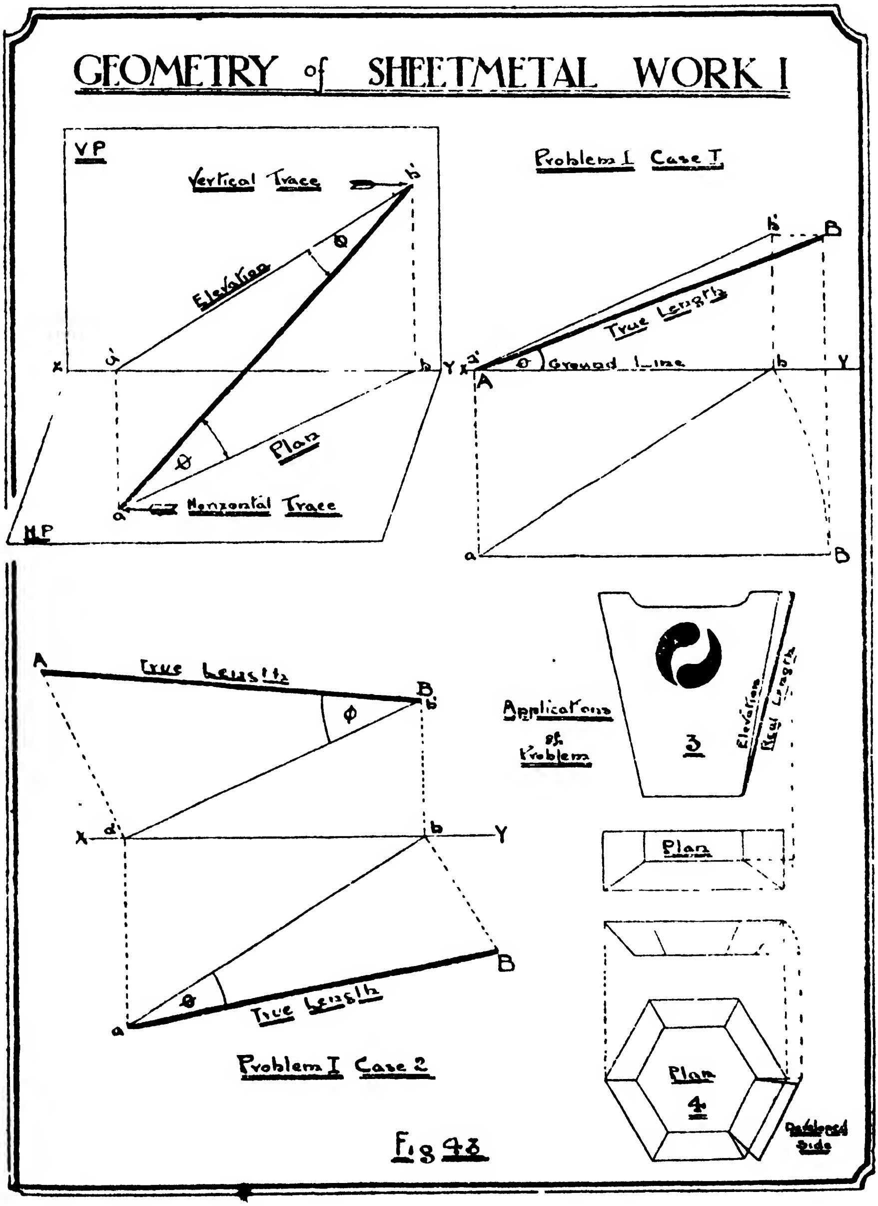


FIG. 42.

The range of craftwork which can be attempted is very considerably widened by having these new materials at one's disposal. Their properties, so remarkably different from those of materials previously handled, arouse new interests, give incentive to constructive and artistic ability, and suggest to the enthusiastic teacher new means of approach, whereby the " practice of the centre," and the " theory of the school," may be brought into more intimate relationship.



A student who has had the advantage of such preliminary training is well equipped for the more advanced work of the metalwork room. As in the learning of a language, a vocabulary having been acquired, he is in a position to study the grammar, and to master technique. But only a brief experience is necessary to impress upon every beginner the need for a deeper geometrical knowledge. Solid Geometry, as represented by the orthographic projection of solids, must be supplemented by another branch—the study of lines and planes, and their inclinations, called Descriptive Geometry.

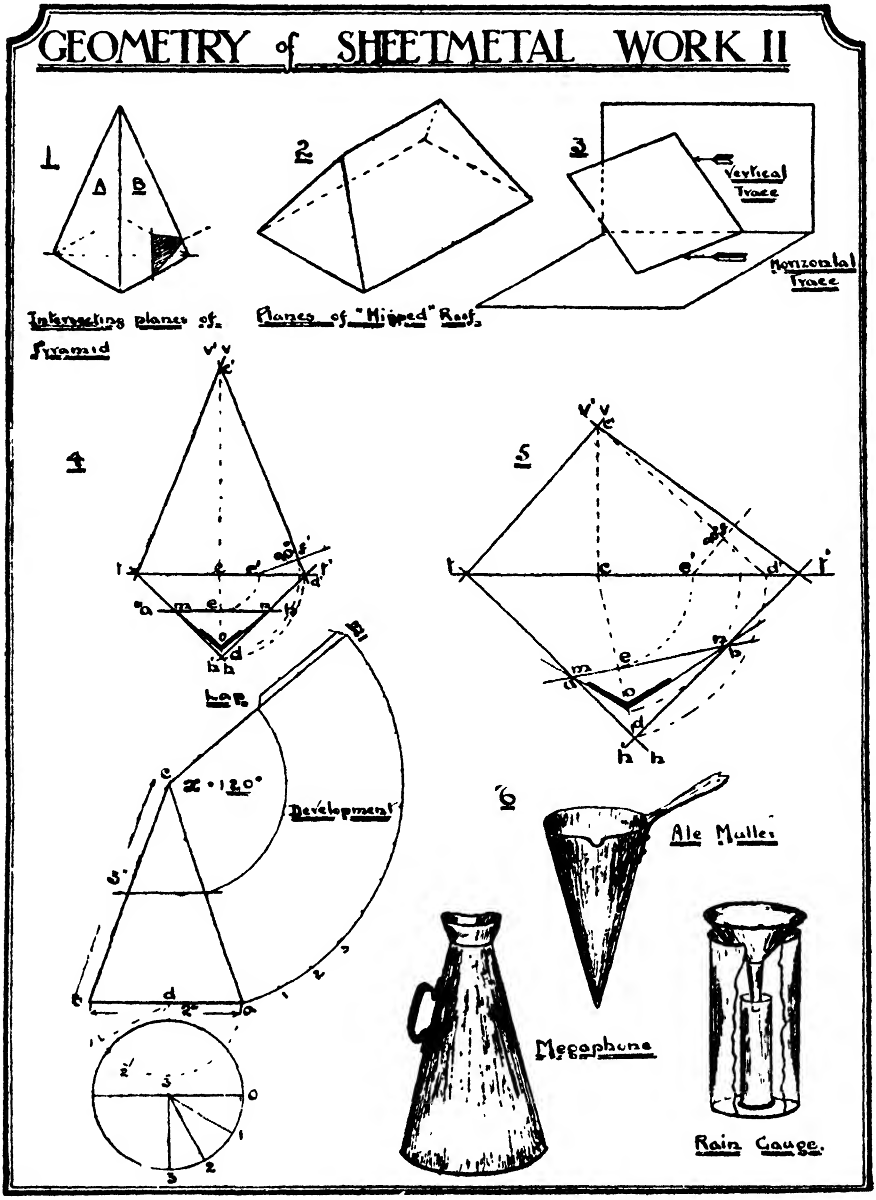


FIG. 44.

To attain proficiency in sheet metal work a student must be a geometrician, for sheet metal work is, of all the metal-working crafts, applied geometry.

Before the object to be made can be folded or modelled into shape, its development must either be drawn on paper, and transferred to the metal, or drawn on the metal direct. Tin plate does not lend itself to clear marking out of lines on its surface by means of a scriber. The covering of tin is so thin that it is easily cut through, and when this occurs rust soon makes its appearance.

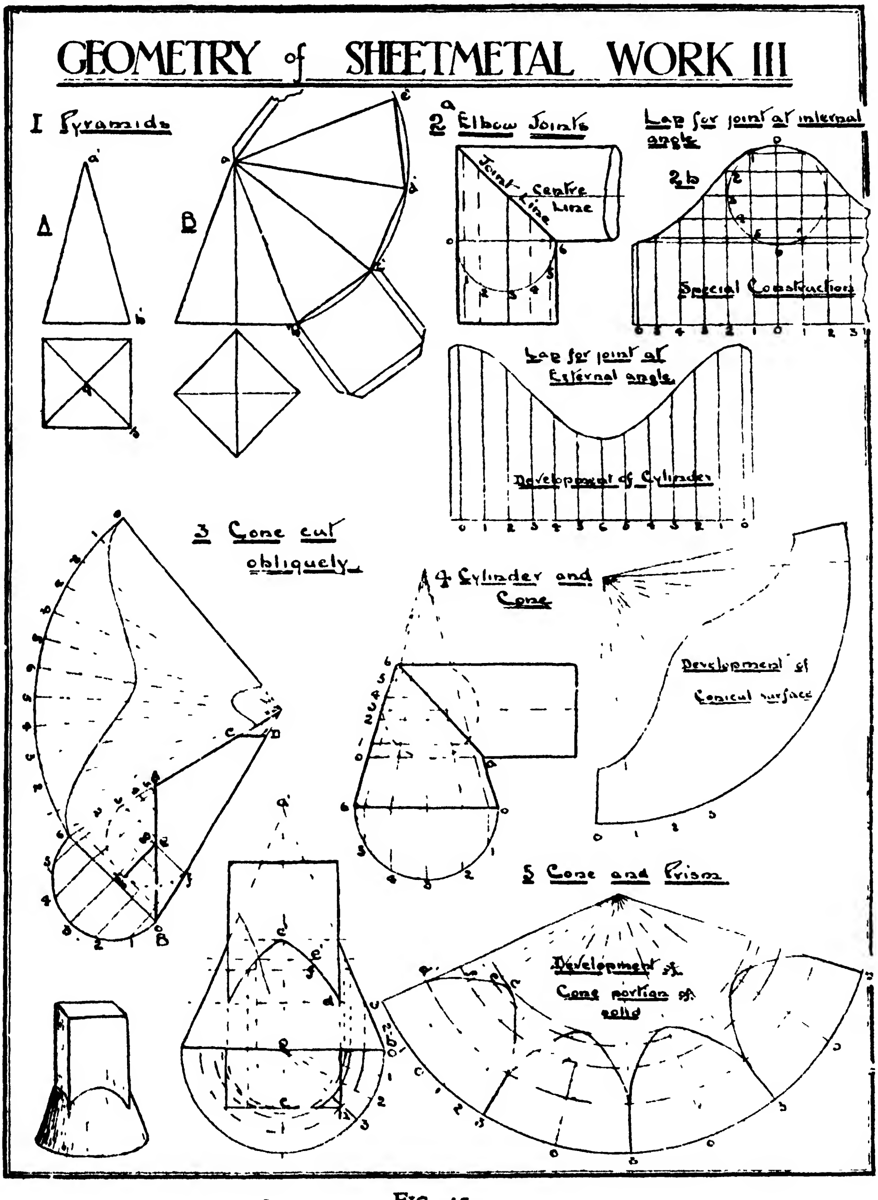


FIG. 45.

Except for the simplest of shapes, it is advisable to make a paper pattern and fix it on the material with an adhesive. The pattern can then be cut round with snips, and removed before the paste has set. Developments often require a much larger surface for construction, than that needed for the actual pattern, so, apart from the avoidance of scratch lines on the metal, it is economical to perform the setting out on paper first, and transfer it to the metal afterwards. A good example illustrating this is the truncated cone (see 6, Fig. 44). Another advantage of the paper template, especially in the case of intricate patterns, is the ease with which it can be folded into shape, and the "setting out" tested before the metal is cut. Sheets of the non-ferrous metals average from 1s. 3d. to 1s. 6d. per pound, so the need for strict economy in cutting is evident.

With few exceptions, all the patterns required in the handicraft room are developments of the surfaces of prisms, cylinders, cones and pyramids, and the problems which present the most difficulty in the "stretch out" of them are :—

I. The obtaining of the true length and inclination of a line when inclined to both planes of projection.

II. Determining the real angle between two planes.

III. The development of the surfaces of cones and pyramids, especially when the taper is slight.

IV. The intersections of surfaces, or interpenetration of solids.

THE GEOMETRY OF SHEET METAL WORK.

Problem 1.—Given the projections of a line *AB*, to find its true length and its inclination to both the vertical and horizontal planes.

Fig. 43 shows a diagrammatic representation of the line *AB*, situated in the first dihedral angle of the co-ordinate planes in such a manner that it is inclined to both. The angle that it makes with the *VP* is indicated by the Greek letter φ (*phi*), and that with the *HP* by θ (*theta*).

Definition.—The inclination of a line to a plane is the angle between the line and its projection on that plane.

The true length may be obtained in two ways :—

1st.—With *a* as a centre, swing the line round until it is parallel with the *VP* (Case I., Fig. 43). The plan and elevation of a point are in the same straight line, so the elevation of *B* is in the projector from *B*, and where it intersects the horizontal line drawn from *b'*.

AB is the true length of the line, and θ its inclination to the *HP*.

2nd.—If the plan of the line is regarded as the base of a right-angled triangle, and the projector *bb'* as the perpendicular, the line itself will be the hypotenuse. Using the base as a hinge, the figure may be turned or rebated into the horizontal plane.

Note.—When a line is parallel to, or lies in either of the co-ordinate planes, its projection on that plane represents its true length.

From *b* draw a perpendicular to *ab* and equal in length to *bb'*, then *aB* is the true length of line, and θ its inclination to the *HP*.

A similar rebatement into the *VP* will give the inclination to the *VP*.

It is good practice to test whether the "true length" corresponds in all four cases.

Applications of this principle are shown at 3 and 4, Fig. 43.

Problem 2.—To determine the real angle between two intersecting planes, when represented by their traces.

When planes intersect each other as instanced by 1, 2, 3, Fig. 44, their intersection is always a straight line. When they cut through the co-ordinate planes, this line is called a 'trace' (the traces of planes are always straight lines.—Euc. xi. 3).

The planes of the pyramid in Fig. 44 are represented at 4 by the traces $v\ t\ b$ and $v'\ t'\ b'$.

Although a square pyramid, the real angle between the sides is not a right angle. It is the angle contained by a third plane inclined at 90° to the intersecting line of planes A and B. In other words it is the true shape of the angle C in the perspective view. To obtain this angle draw a line ab at 90° to the plan of the line of intersection. This line is the horizontal trace of the section plane. The edge view of the plane is obtained by revolving cd into xy carrying the point e with it, and from e' drawing $e'\ f'$ at 90° to $c'\ d'$, the true length of $cd : e'\ f'$ is the altitude of the triangle made by cutting both the given planes perpendicularly. With centre e' turn $e'\ f'$ into xy, and back to the plan. Join to m and n. Then $m\ o\ n$ is the real angle between the planes. Exactly the same procedure is followed if the planes are not equally inclined. 5, Fig. 44, shows a worked example.

This problem occurs very frequently in industrial practice. The carpenter will recognise it as the method for obtaining the "backing" of a hip rafter. The tiler uses it for setting out the template angle for hip and valley tiles, and the metal plate worker when making hoods, hoppers, etc.

Problem 3.—The development of conical and pyramidal surfaces.

Of all the geometrical solids the cone is the one most frequently met with in sheet metal work. Projects like lantern and lamp tops, candle snuffers, ale mullers, and the like, may be complete cones of comparatively short taper, whilst spouts of funnels, handles of scoops and vessels, etc., are generally truncated, and being of long taper, often have their apices at inconvenient distances. This makes it necessary for special constructions to be adopted for their development.

Fig. 44 shows the plan and elevation of a cone. Its development is obtained by taking the slant height or cone generator as radius, and striking the arc $a\ b$. The length of this arc $= \pi d =$ circumference of base. Any of the methods used in practical arithmetic can be applied to measure off this distance. Join $c\ b$ and the sector $c\ a\ b$ is the development required.

A more practical way is to draw the plan or half plan, (see dotted lines) and divide it into a number of equal parts, say twelve. Step off these with dividers along the arc, and join 12 to c, to complete the pattern.

If only a portion of the cone is required as for, say, the "dipper" (Fig. 42), then a second arc is drawn concentric with the first, and a distance away from it equal to the slant height of the object being made.

The angle x may also be calculated from the proportional rule

	Development radius	:	Base radius	: :	Base angle	:	Angle required.
	$a\ c$	:	$a\ d$	: :	360°	:	$x°$
In example,	3″	:	1″	: :	360°	:	$x°$

$\therefore x° = 120°$, which can be marked off with a protractor and the sector drawn.

A few applications are shown at 6 (Fig. 44).

The development of the surfaces of any pyramid is similar in some respects to that of a cone, but instead of taking the slant height as the radius of the circumscribing arc of base, the true length of an edge must be taken. If the projection of the solid is arranged as at '*A*' (Fig. 45), then the true length of the edge *a b* may be obtained by problem I. The more convenient method is to place the pyramid so that an edge is parallel to the *VP*, see '*B*' (Fig. 45), the real length *a′ b′* is then determined straight away.

With *a′* as centre and *a′ b′* as radius draw an arc, and across this arc step off the chords, *bc*. *cd*. . . ., the length of each chord being equal to the length of a side of the base, and the number, equal to the sides of the pyramid—in the example, four. Join *ac*, *ad*, *ae*, *af*. These are the bending lines when folding the material.

If the base and sides are to be in one piece, the quadrilateral or polygon must be added as shown.

When the point *a′* is at an inaccessible distance, as in the case of long tapering articles, special constructions are necessary for drawing the patterns. The two in general use are:—the triangular method, and the segment of circle method. Both are fully explained in the books of reference given.

Problem 4.—Intersection of surfaces, or interpenetration of solids.

When two solids penetrate each other the nature of the line of intersection of the surfaces depends on whether the surfaces are flat or curved. Solids like pyramids and prisms always intersect each other in a series of straight lines, but if one or both of the surfaces be curved the lines of intersection will be curves.

Only very rarely in handicraft classes is it necessary to develop the surface of solids which completely penetrate each other, but it affords excellent practice for an ambitious student to test his knowledge of Geometry by developing and folding up a few examples in thin cardboard.

The problems met with usually take the form of elbow joints and bends, *e.g.*, 2, (Fig. 45), or conical handles intersecting a plane surface as at 3 in the same figure. The intersection of cone and cylinder is also of common occurrence, *e.g.*, spouts, funnels, etc.

These interpenetrations it will be noted, are only partial, and the line of intersection consists only of one closed figure. Example 4 (Fig. 45) shows the partial penetration of a cone and cylinder, and the line of intersection is an ellipse, common of course to both solids.

The "setting out" of the development for an elbow joint is shown at 2a (Fig. 45). This is a general method which is applicable to all joints of this kind when the tubes are non-tapering.

After drawing an elevation of the elbow, describe a semi-circle on the diameter of the cylinder, and divide it into six equal parts. Set off twelve of these divisions along a base line *OO*, and from their respective numbers erect ordinates equal in length to those in elevation, for example the length of ordinate 2 is equal in length to the line passing through 2 on the semi-circle in the elevation. A curve joining the tops of the ordinates completes the development of one arm of the elbow. When bent to shape all the points of the curve will lie in one plane and form an ellipse. A special method which applies only to right angle bends is shown at 2*b*. A circle is drawn equal in diameter to the tubes being joined, and both this and the base line are divided

into twelve equal parts as before. Points on the curve are obtained by drawing construction lines horizontally and vertically as shown.

Pattern 3 is that of a cone cut obliquely. The construction is an important one, as it is applicable in all cases where the surface of an article is a portion of a cone. The thickened outline *A B C D* represents the spout or handle for which the development is required. Complete the cone, and on the diameter of the base describe a semicircle. Divide the curve into six equal parts, and draw lines perpendicular to the base line. Join the points of intersection to the apex. From the points where these radial lines cut the joint line *A B*, draw lines at right angles with the cone axis. Their intersection with the outside line of the cone gives the true length of the radial lines, which can be measured off as required for the development. Both ends are treated in exactly the same way, the construction lines at the smaller end being left out for the sake of clearness.

When folded to shape both the ends will form ellipses, their major axes being *A B* and *C D*. To obtain the minor axis, take a horizontal section of the cone through the middle point *e* of *A B*. With *g f* as radius draw a semicircle, and from *e* erect a perpendicular *e f′* to cut it. Then *e′ f′* will be the semi-minor axis. When cylinders and cones intersect at any angle, in order to obtain their developments, the first essential is to draw in the correct position of the joint line. Draw the centre lines of both solids at the required angle, *e.g.*, at 4 (Fig. 45), this is 90°. With the point of intersection as centre, describe a circle equal in diameter to the cylinder. The outside lines of both solids are drawn tangential to this circle, and the joint line is represented by the line joining their intersections (see 6*a* in the illustration).

It should be noted that the joint line does not pass through the point of intersection of the centre lines. The developments of both surfaces are obtained by the processes already described.

The interpenetration of flat and curved surfaces, as instanced by the cone and prism, 5 (Fig. 45), appears at first sight likely to present difficulties, but the points common to the surfaces of the two solids are readily obtained, if the "method of sections" is thoroughly understood.

The solids are supposed to be cut by a series of section planes. These planes are arranged so that the projection of the sections shall always be straight lines or circles, in plan and elevation. The shapes of the sections are drawn, and a series of points where they intersect is determined. A line through these points completes the projections of the curves of interpenetration. It is a mistake to take too many sections. The best results are obtained with comparatively few section surfaces, but their positions should be very carefully and judiciously chosen.

In the example shown, two critical points on the curve are *c* and *d*, the highest and lowest respectively. To obtain *c′*, project from the half plan the side of the prism until it cuts the cone generator *a′ b′*. A horizontal section at this height contains the points *c′* on all four faces, and it is represented in plan by a circle tangential to the sides of the prism.

To determine *d′* draw the diagonal *g h* of the quarter plan, and turn it parallel to the *VP*, project up to cut *a′ b′*, and again draw a horizontal section, the intersection of this plane with the edges of the prism determines the position of *d′*. Now divide the quarter plan into six equal parts and take sections at heights 1, 2, to obtain the points *e′* and *f′*.

The development of the cone will be understood from the drawing.

ALLOWANCES FOR LAPS, JOINTS, WIRING, Etc.

The developments shown at 3, 4, 5 (Fig. 45) are the "nett patterns" of the conical surfaces. To them must be added certain allowances, which vary according to the type of joint being used to connect the ends, and with the finish, *e.g.*, beading or wiring of the base.

In examples such as these, it is the better plan to mark out the nett pattern on the metal, and then add the necessary laps, etc

ALLOWANCES FOR HANDICRAFT PROJECTS.

For soldered lap joints, $\frac{3}{16}''$.
" rivetted joints, 3 times diameter of rivet.
" beaded edges, $\frac{1}{8}''$.
" grooved seam joints, $\frac{3}{8}''$ on pattern length.
" thrown up, or flanged bottom, $\frac{1}{8}''$.
" Wired edges, $2\frac{1}{2}$ times diameter of wire, or for stout sheet, $2d + 4t$ where d = the diameter of wire, and t = the thickness of metal.

The following problems refer to the projects illustrated in Fig. 42.

1. VORTEX BOX.
Material required :—
Tinplate No. IXX. Brass No. 21.
Method :—
Make an isometric drawing of the box.
Draw the development of the sides allowing $\frac{3}{16}''$ for the lap joint.

NOTE.—The end is to be butt jointed and soldered, and trimmed off afterwards.

The band holds a membrane of thin tracing linen stretched tightly. This, when tapped, expels a smoke ring.

Two small pieces of felt, saturated with hydrochloric acid and 880 ammonia respectively, are put into the box. Dense white fumes of ammonium chloride are given off and fill the box with "smoke."

2. BOX AND SHEATH.
Material required :—
Tinplate No. IXX.
Method :—
Length 8 cm, height 3 cm, capacity, 120 grammes. Calculate the width.
Draw the plan and elevation of the box and the necessary development.
After completing the box make a sheath for it to slide into.

3. PASTRY CUTTER.
Material required :—
Tinplate No. IXX.
Method :—
Make working drawings including a vertical section.
Calculate the length of material required.

NOTES.—Body :—Allow $\frac{3}{16}''$ for lap, and $\frac{1}{8}''$ for the beaded edge.
Handle :—Semi-circular with a $\frac{5}{8}''$ projection at each end for soldering. Edges also beaded.

4. **Dipper.**

Material required :—Zinc No. 13 Zinc Gauge.

Method :—

Draw a plan and elevation and develop the truncated cone (see Fig. 44).

How many grammes of water will the dipper hold ?

Note.—The base is octagonal in shape, and is fastened to the body by means of a soldered butt joint.

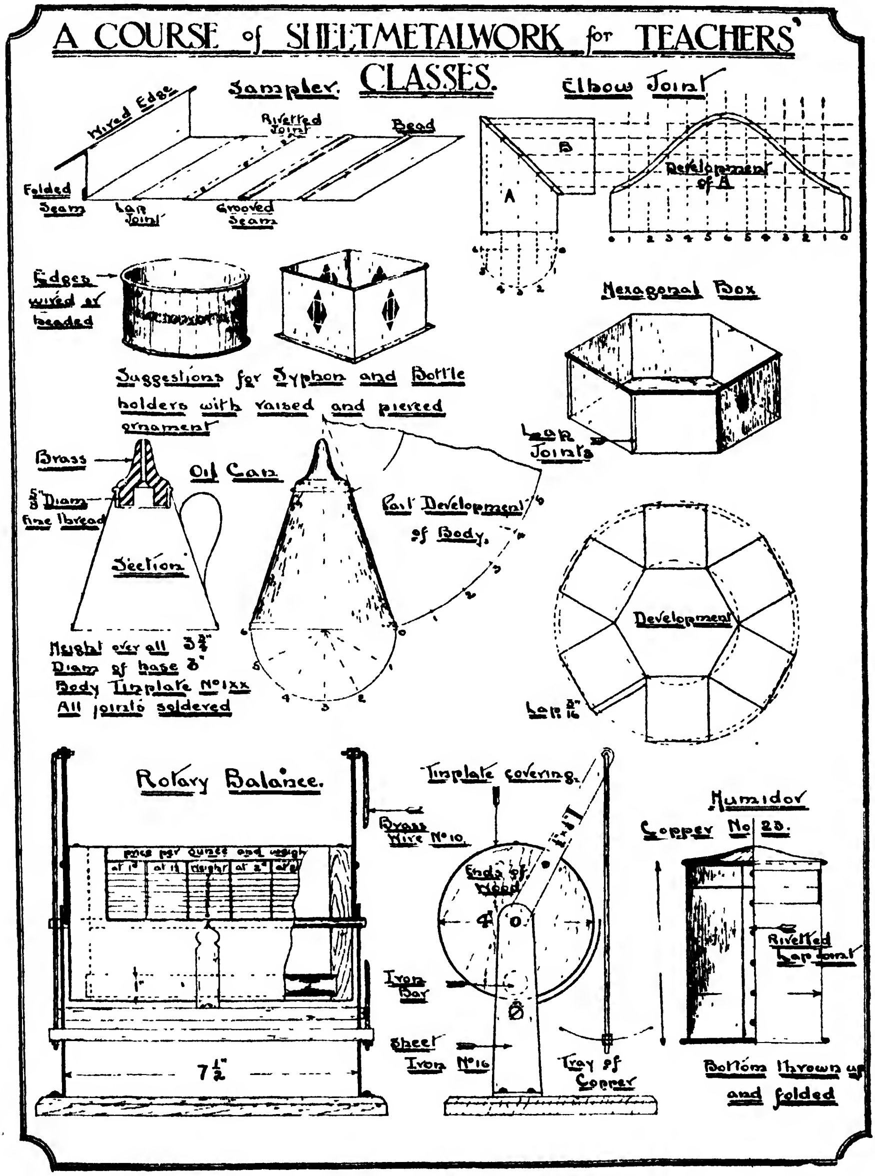


Fig. 46.

5. **Funnel or Tun-Dish.**
Material required :—Tinplate No. IXX.
Method :—
Make the necessary working drawings, adding any dimensions not shown.
Calculate the length of strip *a*.
Develop the conical pieces *b* and *c*.
A device for hanging must be provided.
Notes.—The top edge of *a* may be either beaded or wired.
The edge of piece *b* is thrown up $\frac{1}{8}''$ and soldered to *a*.
When finished to shape, *c* is pushed into *b* from the inside, and fixed by floating a bead of solder round the joint.

6. **Scoop.**
Material required :—Tinplate No. IXX.
Method :—
Draw the developments of the scoop and handle, adding any dimensions that are missing.
If an alternative kind of handle is used, it must be clearly shown in profile on the drawing before being developed and made.

7. **Loaf Tin.**
Material required :—
Tinplate No. IXX. Wire No. 17, Tinman's rivets, $^3/_{32}''$.
Method :—
Make an isometric drawing of the tin. Full size.
Develop and cut out the pattern, making allowances for laps and wiring.
Why are rivets more suitable as fastenings than soldered joints ?

8. **Trinket Box.**
Material required :—
Brass or Copper. Gauge 22.
Method :—
The drawing shows a suggestion for a trinket box with a push on lid.
The body is made of three pieces, the middle piece being folded to form two sides and a bottom.
The dotted line round the top indicates a soldered joint fixing the strip of metal $\frac{1}{2}''$ deep, which fits closely to the inside of the box, but also permits of comfortable sliding on and off.
Make an elevation and a plan, and develop pieces *A* and *B*.
Suggestions for ornamentation are shown, but it is desirable that you should apply your own.

9. **Hydrometer.**
Material required :—
Tinplate No. IXX. Brass Wire No. 10.
Method :—
Two developments are necessary for the cylindrical and conical members of the instrument.
Draw and cut out these.

NOTES.—Lap joints are employed for the side joints of the developed pieces.

The top and bottom cones have their bottom edges thrown up $\frac{1}{8}''$ to fit round the cylinder ends, and are fixed by soldering.

The pan is shaped in a "dishing" block with the ball peen of a hammer.

It is advisable to allow the brass rod to run right through the body of the hydrometer, and fix the various members to it with beads of solder.

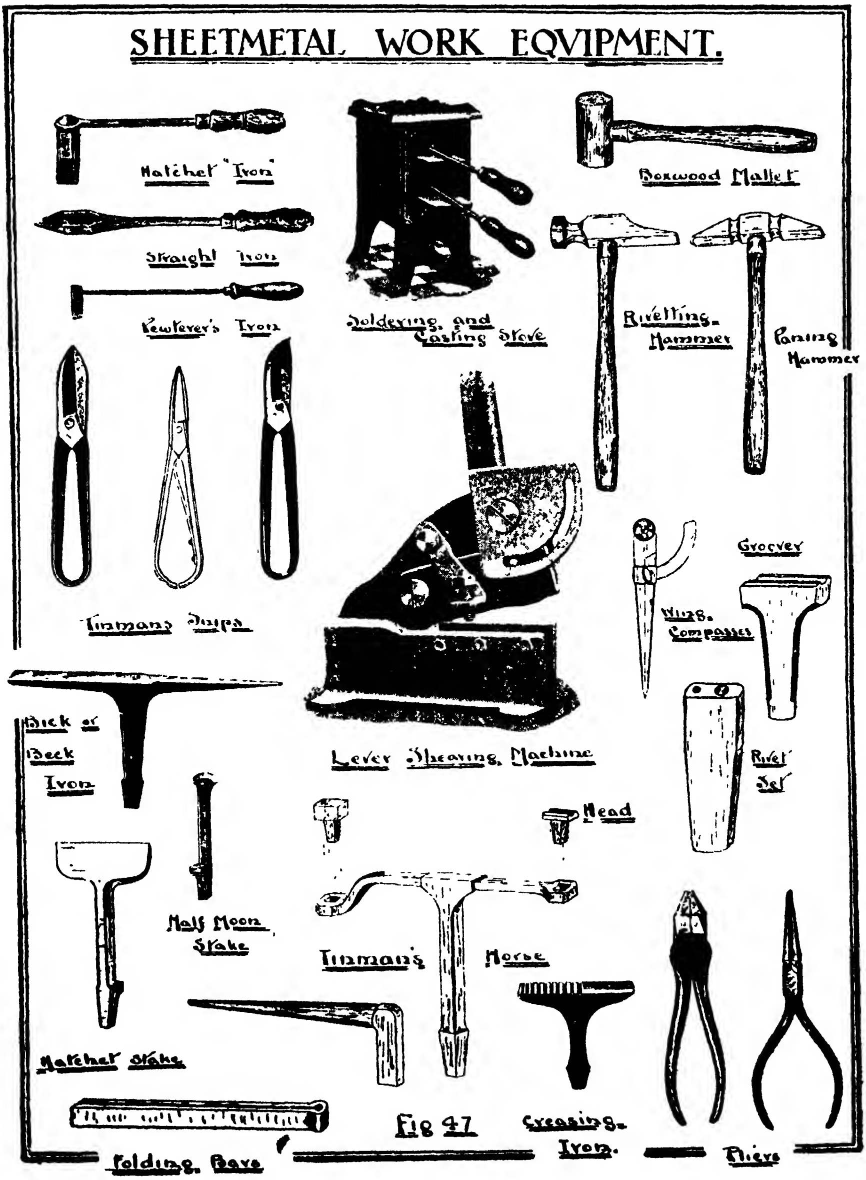


Fig 47

EQUIPMENT.

The experience of teachers in charge of metalwork classes confirms the opinion that sixteen should be the maximum number of students entrusted to one teacher, and for purposes of organisation, these are best divided into groups, so that eight are engaged on vise work, four on forge, and four on sheet metalwork at the same time, with practice in lathe work as opportunity affords and necessity arises.

It will be seen that equipment for four students engaged in sheet metal work need not be very expensive, especially if a careful selection be made of the necessary tinman's stakes. These are often carelessly ordered, and stakes, much too heavy, and standing too high in their sockets, are supplied. For fashioning hoods, hoppers, and the large utensils made by the metal plate worker, these large stakes are excellent, but they are quite unsuitable for the work of the handicraft room. With the exception of a few of the smaller tools it is only necessary to provide one of each article.

TOOLS AND APPLIANCES (see Fig. 47).

THE STOVE.—There are several designs of small gas-heated stoves suitable for heating the straight pattern soldering bits, but if "hatchet irons" are used, and these for all round utility are to be preferred, it is necessary to have a wide aperture through which to insert the tool end for heating. The stove illustrated satisfies all the requirements of an ideal heating device, viz. :—

i. Heat is quickly raised.

ii. Fitted with two burners, the gas consumption can be halved when full heat is not required.

iii. Two irons may be heated at the same time.

iv. Provision is made on the top for accommodating a lead pan, when metal for casting is being melted.

FIG. 48.—EQUIPMENT FOR LIGHT-METAL WORK IN A WOODWORK ROOM.

STAKES.—These, the distinctive tools of the sheet metal worker, are usually mild steel forgings, faced with cast-steel, and are sold by weight. The bottom end of each stake is made taper to fit into a socket which is let into the bench top.

(i.) *Hatchet Stakes* are used for bending an edge to an acute angle. The face varies in length, one about 8″ long and weighing 9 lbs. is the most serviceable for handicraft purposes.

A piece of stout sheet iron screwed to a wood support, and having its top edge bevelled, can be made to serve the purpose for the tinplate work practised in a woodwork centre.

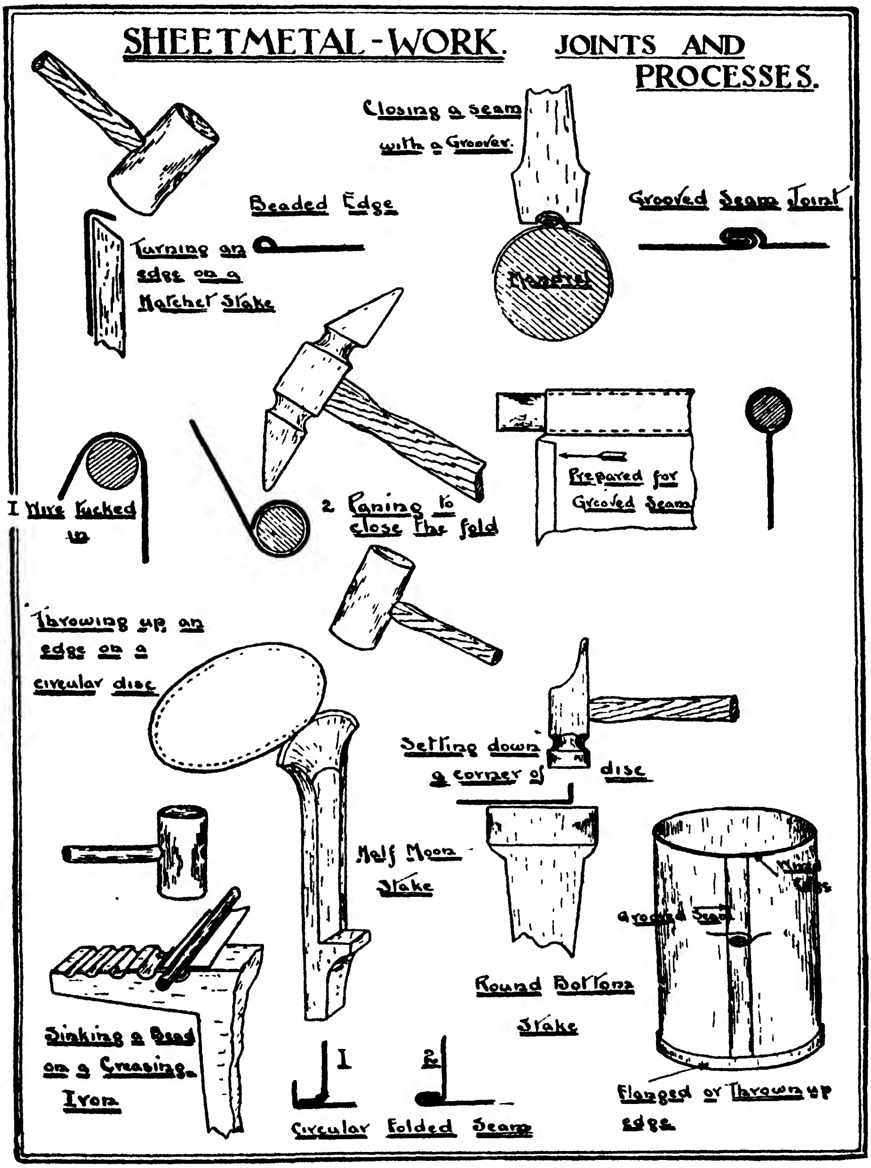


FIG 49

(ii.) *Half-Moon Stake.* The illustration shows the use of this appliance when " throwing up " an edge on a circular piece of metal, preparatory to wiring or " snuffing on " the bottom of a can. The edge is an arc of a circle, and a suitable weight is 4 lbs.

(iii.) *Round Bottom Stake.* After an edge has been thrown up or flanged on a half-moon stake, the material will probably be buckled. It can be straightened by hammering gently on a round bottom stake, and the edge " set down " to sharpen the corner as shown in Fig. 49. Diameter of stake, $2\frac{1}{4}''$. Weight 5 lbs.

FIG. 50.—MAKING A SHARP RIGHT-ANGLED BEND IN FOLDING BARS.

(iv.) *Beck or Bick Iron.* The long beck of this stake is used when shaping long conical work, and the anvil end for squaring corners and light rivetting. Stakes of similar shapes, but of much larger sizes, are known as Funnel and Extinguisher stakes. A convenient size of iron for student's use is one $22''$ long, weighing about 10 lbs.

(v.) *Creasing Iron.* The use of this tool is shown in Fig. 49, when it is desired to work a bead on a piece of flat sheet. Care must be taken to ensure the line of the bead and the groove in the creasing iron being co-incident before the wire is struck and impressed into the metal. A wired edge can also be folded by placing in a suitable crease, and the fold closed with a mallet or paning hammer. Weight 8 to 10 lbs.

(vi.) *Tinman's " Horse."* This is a combination stake, the sockets at head and tail receiving the shanks of various small heads. There are also similar stakes, which have a three arm piece like a cobbler's last, and a socket at the end of each arm to hold the heads.

Other necessary Tools are :—

1. Folding Bars.—These are made of cast steel 1″ to $1\frac{1}{4}$″ × $\frac{1}{2}$″. No tool is so suitable for bending thin plate to a sharp right angle. When the metal is gripped between the bars (see Fig. 50), the line of the bend is kept perfectly straight.

Suitable lengths to requisition :—One pair, 12″.
One pair, 9″.

Small Tools illustrated in Fig. 47.

Mallets :—2 Boxwood 2″ diameter.
„ 1 Hide.

2. Soldering "Irons."—There should be no need to purchase except at the commencement of the Course, all renewals being made by students (see Vise Work). Irons should be of sufficient volume to retain heat but should not be unwieldy ; 4 to 8 ozs. are heavy enough for the average student to handle comfortably. For all round work the hatchet shape will be found the most convenient, the straight irons being particularly suitable for soldering inside seams.

Fig. 51.—Punching a Hole in Tinplate on a Lead Block.

3. Shears.—For cutting thick plate it is necessary to have either a pair of Scotch shears, or a small machine like the one illustrated in Fig. 47. There are various designs on the market known by such names as " Little Giant," " Big Dwarf," etc. The bottom flanges are bolted to the bench-top, and the jaws are operated by a hand lever. Plate up to $\frac{1}{8}$″, and rod stuff up to $\frac{5}{16}$″, are readily cut with the smallest size machine.

4. SNIPS, TINMAN'S.—These are for cutting and trimming thin sheet. 2 Pairs straight, 10″, and 1 pair curved are necessary.

5. Snips, Pewterer's	1 pair 7″ long.
6. Wing Compasses	2 pairs, 6½″ legs.
7. Scribers	4 (Renewals made by students).
8. Rules, Brass	4
9. Try Square	1 The blade 9″ long and flush with one side of the stock.
10. Hammers	1 paning. 1 rivetting.
11. Groovers for closing seams	1 ¼″ 1 $\frac{3}{16}$″ Care should be taken to grind the outer edges round, to prevent them cutting into the work.
12. Hollow punch	1 ½″ diameter. See Fig. 51.
13. Rivet Sets	1 for $^3/_{32}$″ rivets. 1 for ⅛″ „ These have a hole and hemi-spherical cavity in the same tool. The hole is for closing the joint, and the recess for forming the snap head. See Rivetting.
14. Mandrils and Formers.	An assortment of various diameters, both cylindrical and taper should be made and kept in a convenient position in a rack.

There are numerous other small tools and appliances in the " kit " of a sheetmetal worker, which can either be made or bought as necessity arises.

SOLDERS—(*solidare—to make solid*).

Those used by the tinsmith are alloys of tin and lead, and being fusible below a red heat are termed soft solders. Bismuth added to solder has the effect of lowering the melting point very considerably, and when present in larger quantity than any of the other constituent metals, the resulting alloys are fusible in boiling water.

ALLOYS USED AS SOFT SOLDERS.

Name of Solder.	Tin.	Lead.	Bismuth.	Melting Point Fah. (approx.)
Plumbers'	1	2	–	440°
Tinman's	1	1	–	340°
„ Fine ..	2	1	–	320°
Pewterer's	1	1	1	235°

The high percentage of lead in plumbers' solder causes the melting point to be high, but the metal withstands the action of weather and water better than tin.

An increase in the tin content of a solder adds to its flowing property, the quality can be estimated by bending a stick of the solder close to the ear. If it contains a high percentage of tin a distinct crackling sound will be heard

PROCESS OF SOLDERING.

The technical process of joining metal to metal by solders is known to almost everybody. All text-books on the subject describe the cycle of operations with a clearness which makes it impossible for a novice to go wrong, but the physical and chemical aspects of soldering appear to have received little attention, and here, it would seem we have a field for scientific investigation.

If we put a drop of water on a clean surface, the liquid spreads itself out indefinitely and wets the surface, but if the surface be greasy, the water forms itself into globules ; the surface tension, or strain, in its " skin," together with the cohesion of its particles, are great enough to overcome the forces of gravity and adhesion, which tend to draw every particle of each drop downwards, and flatten out the globule.

A similar condition is observed if we drop a bead of hot solder on a piece of hot metal not chemically clean. Instead of spreading, the solder will retain a globular form, being surrounded by a solid skin of its own oxides.

The film on the metallic surface (usually an oxide) is of sufficient thickness to prevent the metals from adhering together and forming an alloy. The removal or dissolving of this film, by means of a flux, so as to leave the base metal chemically clean during the joining process, has always presented a problem to metalworkers and chemists. In the case of Aluminium it is still unsolved, no flux or solvent being known which will dissolve aluminium oxide quickly enough to allow of the metal being soldered with a copper bit.

Fluxes (*fluo, I flow*) have a threefold function to perform, viz. :—

I. To cause the solder to flow.

II. To cleanse the surface of the base metal.

III. To prevent the further formation of oxide.

Metals which oxidise slowly at the soldering temperature may, after cleaning, be coated with organic fluxes, like resin or tallow, which prevent further access of atmospheric oxygen. The plumber in " wiping " a joint uses tallow, and pours solder on the scraped ends of the pipes being joined. The solder is immediately enveloped in a layer of molten fat, and alloying takes place before any oxidation can occur.

Electricians use resin as a flux when soldering electric fittings. Acid fluxes set up electrolysis, and should never be used on this class of work; but it is essential that the joints should be scraped thoroughly clean if perfect alloying is to take place. Resin, it must be remembered, is not a cleanser, and for this reason is regarded only as a partial flux.

In cases such as these, the only requirement of a flux is that it should be present throughout the process, and remain liquid without serious decomposition at the soldering temperature.

But some materials cannot be scraped without destroying the surface, *e.g.*, tinplate, and the normal condition of all metals, is to be covered with an oxide film of varying thickness. To dissolve this film, and prevent further oxidation during soldering, inorganic fluxes, usually chlorides, must be brought into use.

ZINC CHLORIDE.

$ZnCl_2$ "Killed Spirits." This, the most serviceable of all fluxes, can be prepared in the handicraft room by pouring hydrochloric acid on pieces of scrap zinc in an earthenware dish. Hydrogen is given off in a dense and irritating vapour, and the operation should be performed near an open window or flue. When the zinc and chlorine are combined, the acid, commonly known as "spirits of salts" is said to be "killed."

$$Zn + 2HCl = ZnCl_2 + H_2$$

Zinc + Hydrochloric Acid = Zinc Chloride + Hydrogen.
"Spirits of Salts." "Killed Spirits."

When ebullition has ceased, the liquid should stand for a few hours before being poured off into a 'winchester' for storage, an equal amount of water being added. If any free acid is present, owing to insufficient zinc being used, it may be neutralised by putting a piece of alkali: —sal ammoniac, about the size of a walnut, in the bottle. Free acid can easily be detected by the black stain it makes on tin plate when applied during soldering.

TABLE OF FLUXES FOR SOFT SOLDERING.

	Name.	Metals.	Remarks.
Organic.	Tallow	Lead	
	Resin	All Metals	Does not remove oxides. Does not induce subsequent corrosion.
	Gallipoli Oil Venus Turpentine	Pewter Britannia Metal	Suitable for metals which oxidise slowly and with low melting points.
Inorganic.	{ Zinc Chloride 1 Water 1 }	Tinplate, Copper Brass, Iron	Should be washed off completed work, or rust will quickly make its appearance.
	Hydrochloric Acid (very dilute)	Zinc	No other flux gives satisfactory results.
	Ammonium Chloride (Sal ammoniac)	Copper	Used by Copper-smiths for tinning copper vessels.
Patent.	"Fluxite"	All Metals	A paste flux, non-corrosive.
	"Batteline" "Baker's Fluid"		Convenient when large quantities are not required.

To return to the bead of solder on the hot plate. If both be touched with a few drops of zinc chloride or other suitable flux, the body metal is made chemically clean, and the solder becomes bright and free moving, spreading itself out and covering the surface which has been in contact with the flux.

The change from a non-flowing condition has been brought about by :—

i. A lessening of the surface tension of the solder, by the flux and the application of heat.

ii. A change in the nature of the surfaces in contact, allowing clean solder and clean body metal to come into contact.

From this we may form the general conclusion that any solderable metal may be alloyed with molten solder if both are chemically clean.

TINNING THE BIT.

Before the " iron " will pick up the molten solder the end must be coated with tin. This is done by heating it in the stove until the green flame of copper is seen, then filing the end, and plunging it into a resin bath on a tile before oxidation can take place. If it be now rubbed against a piece of solder on the tile, the solder will spread over and cover the filed surface.

Two practices, common both in schools and workshops, must be condemned :—

Firstly, that of picking up solder from a piece of tinplate. The solder rapidly deteriorates from repeated oxidation every time the hot iron is brought in contact with it. It is never as bright and free moving as when gathered from a resin bath on a tile made for the purpose.

Secondly, cleaning the hot end of the bit by dipping it in the flux pot. If this be done every time the bit is withdrawn from the stove, a film of oxide is dissolved in the flux, which, of course, soon becomes dirty and ineffective. A piece of rag or a lump of sal ammoniac should be kept handy for wiping the iron before using.

When once tinned, a soldering iron should remain in a fit condition for use for quite a long time. Judgment is required not to overheat it and burn off the tinning. The temperature indicated by the green colour of the flame should not be exceeded.

When drawing the iron along the joint, the movement should be performed very slowly, in order that the temperature of the base metal may be raised slightly above that of the melting point of the solder. Perfect alloying cannot take place otherwise. To make a sound soldered joint it is essential to have :—

i. sufficient heat ;

ii. as small a quantity of solder as possible ;

iii. a slow uniform movement of the bit.

Added interest and increased educational value will be given to the work if the co-operation of the science teacher can be obtained, and a few experiments on surface tension, conductivity, properties of alloys, etc., be performed in the laboratory, prior to, and concurrent with the discussions and practical work in the handicraft room.

SWEATING.

Soft soldering is usually performed along the laps and seams of tin-plate, zinc, etc., but it is frequently necessary to join wider surfaces together by this process. When a brass bush requires re-boring the two halves of the bush must be coated with solder and joined together by pressure and heat to form one piece, and handles, knobs and feet are similarly joined to bars, rods and plates by this method of sweating when other methods such as rivetting and screwing are inapplicable.

The surfaces to be united must be made perfectly true and well fitting, treated with flux and tinned or coated with solder. The tinning may be done with a soldering bit if the material is thin or of small volume, but if it is thick and likely to absorb the heat from the bit the material itself must be heated to approximately the melting point of the solder. When tinned the surplus solder is wiped off, the parts then placed together and heated again over a burner, or with a blow pipe until the solder melts.

Pressure is then applied to squeeze up the joint and is maintained until cold.

CHAPTER XI.

Brazing.

BRAZING or hard soldering is the joining of metals by means of a fusible alloy, *e.g.*, spelter, at a temperature above red heat.

To obtain this temperature, varying from 600° to 700°Cen., it is necessary to use a Bunsen blow pipe. Fig. 52 shows a suitable type fitted with two valves, one to regulate the gas and the other the air supply.

The blast may be supplied by a foot bellows, and this method has the advantage of allowing the brazing to be performed in any part of the room, on a small portable hearth like the one illustrated in Fig. 53, which shows a small iron tray with a thick piece of asbestos in the bottom.

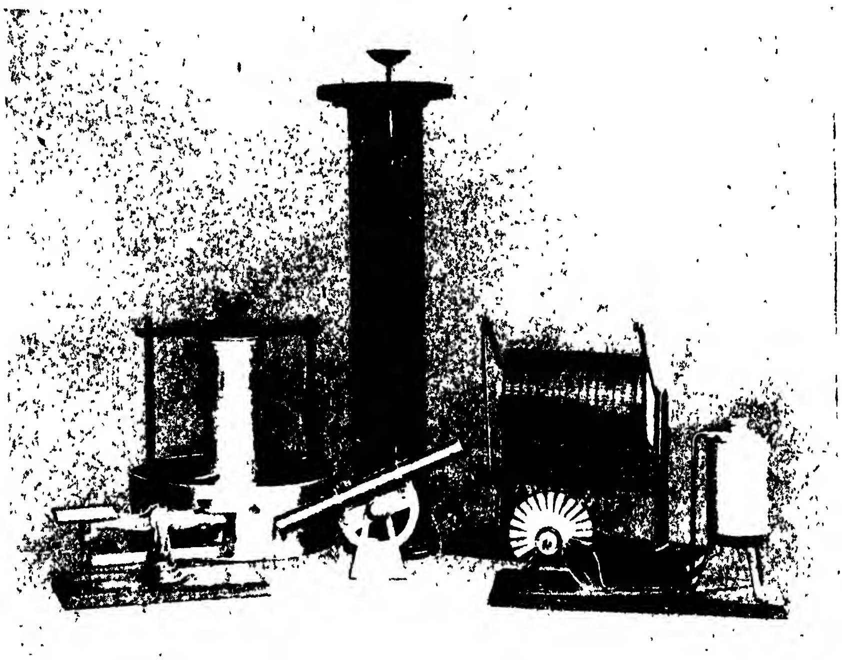


FIG. 51a.—A SCIENCE GROUP IN SHEET METAL.

The blast from the smithy fire may also be utilised, and if space will allow of it, a brazing pan, Fig. 52, fixed in a convenient position; or, as another alternative the smith's hearth itself may be made use of for packing up the work. (See Fig. 54). Whichever method is employed, the quick generation of heat and its conservation are the objects to be achieved. A good blowpipe with a carefully regulated flame will localise the heat at the spot required, and linings and packings of non-conductive materials, like cinders, asbestos, pieces of fire brick, etc., on the hearths, will prevent its dissipation.

HARD SOLDERS.

Brazing solder is called " spelter," a name which is also given to Belgian zinc. The two must not be confused, as the spelters under review are alloys of copper and zinc in varying proportions. The higher the copper content the higher the fusing temperature, but the stronger the joint. Spelter for brazing brass must contain a considerably greater percentage of zinc than the base metal, so that the solder will fuse without danger of melting the work at the joints.

TABLE OF BRAZING SOLDERS.

Copper.	Zinc.	Fusing Point (Cen.)	Where Used.
3	2	610°	Thin iron plates. Tube seams. Copper work.
2	1	700°	Heavy iron work.
1	1	550°	Brass.

Scrap pieces of sheet brass may be used for hard soldering, but the fusibility should be tested before being applied to work.

Granulated spelter is sold by the pound, and in this form is handy for mixing with the flux paste. The fusing point should be stated when ordering. For handicraft purposes a very convenient brazing compound is now on the market. A low fusible spelter, it is sold in sticks, the sticks being marked as shown in Fig. 52, to indicate whether suitable for iron or brass. Whilst it is claimed that a flux is unnecessary when using this compound, experience goes to show that it runs admirably in the presence of borax. Various uses of the preparation are indicated.

FLUX.

The only flux used by braziers is borax, which is perfect in its action. Oxides on the surface of metals are dissolved by it and changed into borates, whilst at a red heat the borax vitrifies, and forming a glassy film over the metal, prevents the further access of atmospheric oxygen.

When ordinary borax is heated it effervesces, owing to water of crystallisation being driven off. This bubbling tends to displace the spelter from the joint, and it is a wise precaution to prepare the borax by first roasting, and then pounding it in a mortar with a pestle. The powder formed is called " borax glass," and when made into a paste with spelter and water, can readily be applied to the work with a camel hair brush (borax pencil), if only a small amount is needed, or with a spatula if the metal has been previously heated.

The chemical action of borax during the brazing or hard-soldering process may be demonstrated by an interesting experiment. Students with a knowledge of chemistry may be familiar with the borax bead tests for the identification of the metal in metallic compounds (oxides). This experiment may be performed in the metalwork room, and will emphasise the importance of the use of fluxes in obtaining chemically clean surfaces, i.e. surfaces free from oxides, whenever metals have to be joined by heat. On the end of a platinum wire mounted in a piece of glass tubing make a small loop and heat it to redness in a Bunsen flame. Dip the hot end into powdered borax, which will adhere to it, and re-heat. The borax will froth up, water of crystallization be driven off, and a clear glass bead will be formed in the loop. Allow a few grains of black copper oxide to rest on the bead and again place in the flame. In a few moments the borax will fuse, and when allowed

to cool, a green transparent bead will have formed. Under these conditions the copper oxide forms a copper borate with a characteristic green colour. Other metals give different colours :—cobalt, a rich blue, and iron a deep bottle green.

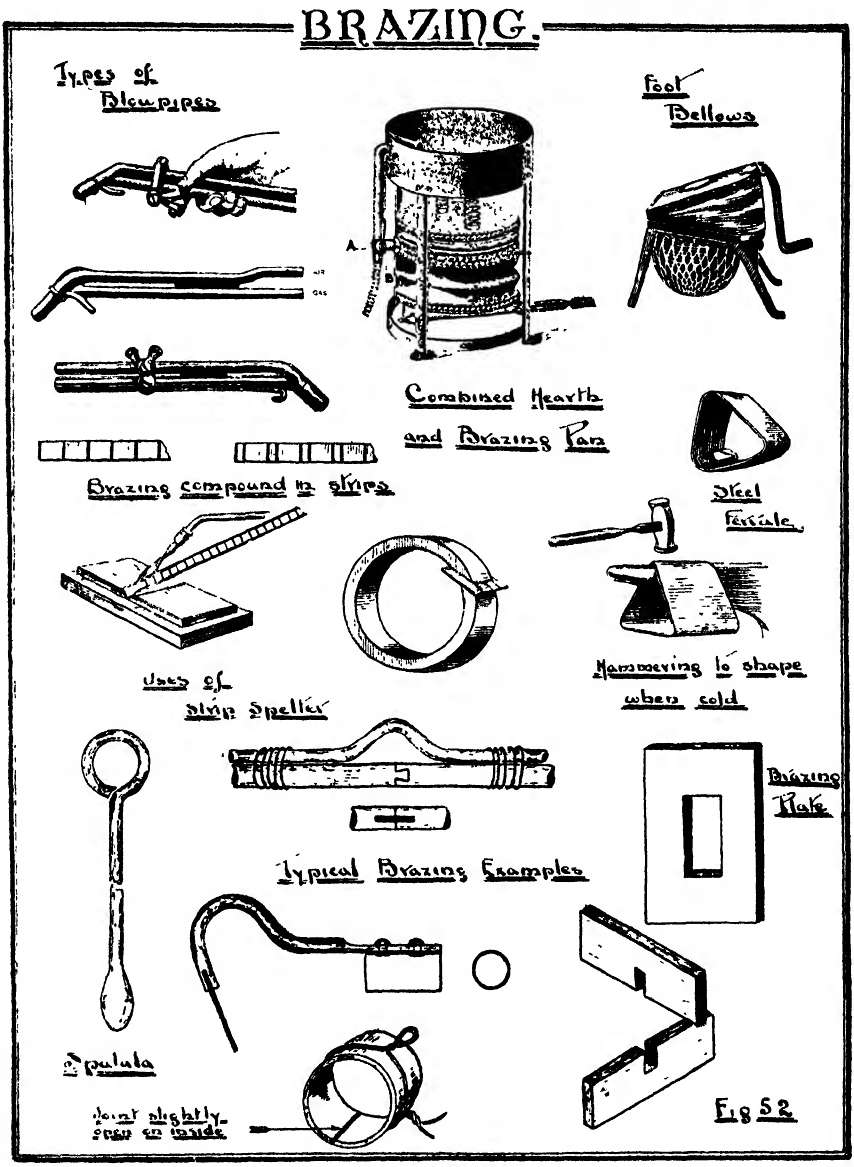


Fig 52.

PREPARATION OF WORK.

Joints to be brazed should never be 'driving fits.' Without being actually slack, the parts should go together easily in order to allow the molten spelter to run freely through the joint, and alloy itself with every surface. The butt joints of rings, ferrules, etc., should be eased off slightly on the

inside for the same reason, see Fig. 52. The test of a sound brazing job is the appearance of an unbroken brass line at any section of the joint. The expansion of the metal when heated tends to open the joints, and precautionary measures against this are illustrated in Fig. 52. Soft iron binding wire is wound round the copper napkin ring, loops being formed at intervals to allow of subsequent tightening and cramping the ends of the butt joint together, whilst the joints of straight work are kept in position, and the work in alignment, by the use of guide bars.

The surfaces to be brazed should always be made bright. Many braziers also rub them with a piece of blue stone (Copper sulphate), or paint the joint with a solution of it.

FIG 53. - BRAZING ON SMALL PORTABLE HEARTH

THE BRAZING PROCESS.

After packing up the work, raise to a red heat quickly and then apply the paste with a spatula. The temperature must now be raised gradually to avoid displacing the spelter. Just at the point of fusion, a gentle tap will assist the solder to flow into, and through the joint. When set, the metal should be allowed to cool slowly, as quenching at a red heat tends to crack the spelter and distort the work.

The glassy scale formed by the borax on the surface around the joint can be removed by immersing in a hot solution of alum. Acid pickles are also used to dissolve the oxide and borax.

When brazing brass care must be taken to see that no lead or solder is on the metal, as at a red heat these metals eat into brass and cause it to become pitted.

SILVER SOLDERING.

Silver Solder is a hard solder and is used in the same way as spelter. It melts, however, at a lower temperature, and can therefore be used to solder brass, copper, and silver.

The price of silver solder is about 3s. 6d. per oz. and it is sold in sheets from $^1/_{32}$" in thickness. It can be made much more cheaply by melting scrap pieces of silver with low fusible brass. When the two metals are melted together and thoroughly mixed, the molten globule is turned out on the bench and

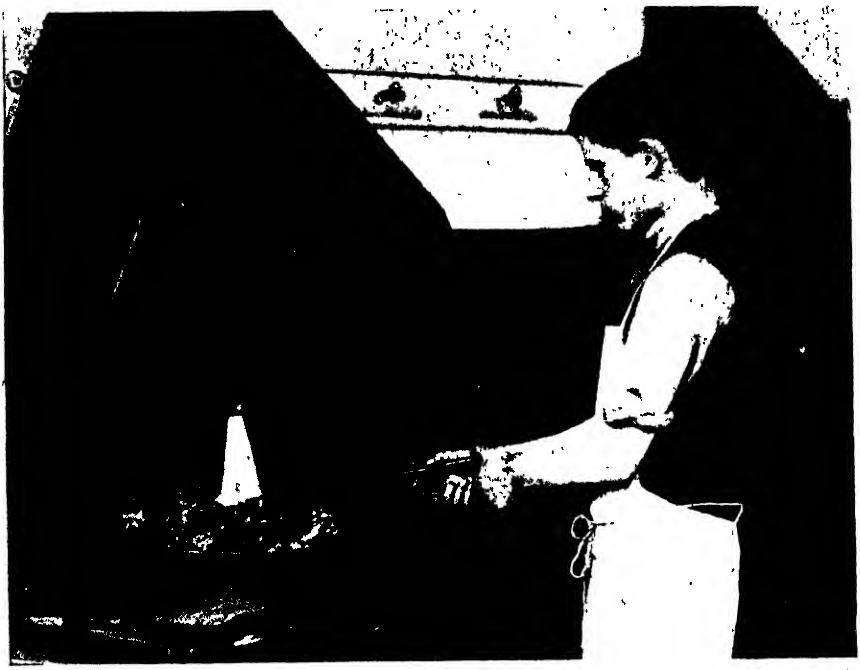


Fig. 54.—Brazing on Smith's Hearth.

flattened with a heavy weight such as a chipping block. Suitable proportions for two useful solders which can be used on either copper or brass are as follows :—

No. 1. Silver 2 Brass 1.

No. 2. „ 7 „ 2.

The latter fuses at a lower temperature than No. 1 and has a much whiter appearance.

The process of silver soldering is very similar to that of brazing, but before wiring the parts together and applying the flux (borax) and solder, it is always advisable to clean the metal by immersing it in a pickle consisting of 1 part sulphuric acid and 12 parts of water. If copper or brass are heated to redness and dropped into the pickle (care being taken to avoid splashes), they will be both annealed and cleaned.

Only a very small amount of solder is necessary, and it can be cut from the sheet into small pieces (paillons) about $\frac{1}{8}$ of an inch square, and laid round

the joint, see Fig. 55, or the end of a strip of it can be held with pliers in contact with the joint, and melted with the blowpipe flame.

When cold, the work should again be immersed in the pickle, to remove any oxide that may have formed, and dissolve any excess of borax. A final washing in cold water leaves the work ready for finishing

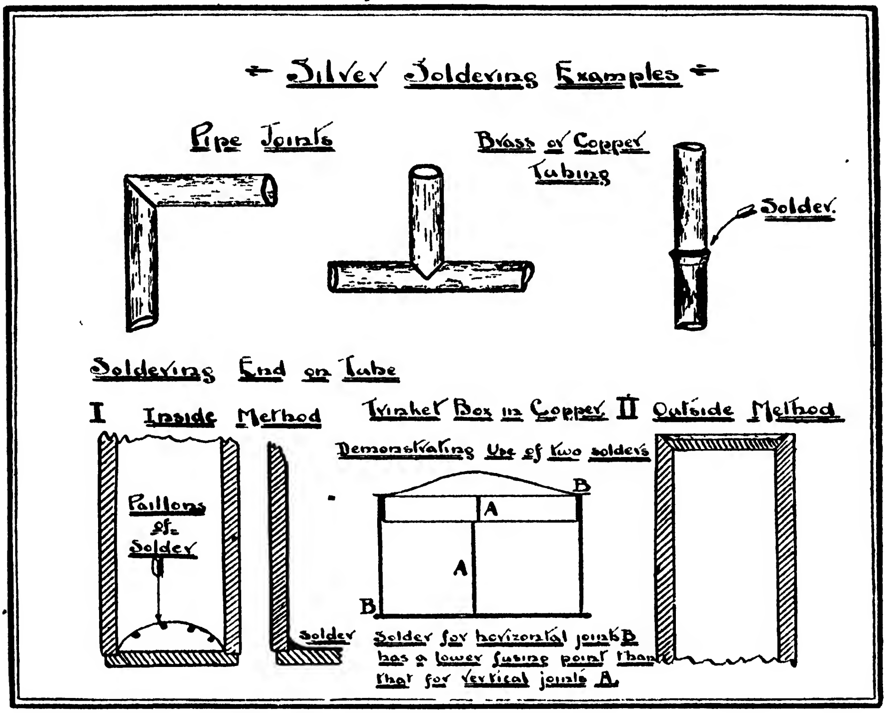


FIG. 55.

NOTES ON SHEETMETAL WORK.

TINPLATE is thin sheet iron or mild steel which after being annealed, scoured, and pickled, has been coated with tin. The tinning is done by dipping the clean plate in a bath of molten tin and then passing it between rollers, which regulate the thickness of "tinning" left on the plate. The tin coating acts as a protection against corrosion. Should it be cut through or damaged, galvanic action is quickly set up, causing the plate to rust rapidly.

Tinplates are known by their "strength" marks and not gauge sizes, *i.e.*, No. IX., No. IXX. (No. 1, 1 cross, No. 1, 2 cross, etc.). The stock sizes of sheets are 14″×10″, 20″×14″, 28″×10″, 28″×20″. The most suitable plate for Handicraft purposes is No. IXX. which approximates in thickness to No. 26 on an Imperial Standard Wire Gauge, see Fig. 56.

TINPLATE TABLE.

Strength Mark.	Name.	Approx. Gauge Thickness.	Price.
1 C	No. 1 Common	30	per plate
1 X	„ 1, 1 Cross	28	28″×20″
1 XX	„ 1, 2 Cross	26	9d. to 1/-
1 XXX	„ 1, 3 Cross	25	

Terne Plates are coated with tin and lead, and have not so bright an appearance as tin plate.

Galvanised Plates are coated with zinc. When soldering, the treatment is very similar to that of zinc, hydrochloric acid being used as the flux.

ALLOYS.

An alloy is a combination of two or more metals. This combination may be effected by fusion or by some other process, as electro-deposition, or cementation. Most alloys may be regarded as a solidified solution of one metal in another.

The qualities of an alloy cannot be predicted from a knowledge of those of the constituent metals; thus the density may be greater or less, the melting point is generally lower, elasticity may be increased or diminished, malleability and ductility may be greater or less, and the resistance to tension, torsion or compression may differ considerably from those of the metals forming the alloy. A casual examination of an alloy would give the impression that some chemical combination has occurred, but that this is not the case is abundantly clear on further and fuller investigation. To secure chemical combination the elements must be united in certain definite proportions, but alloys are formed in all sorts of irregular and indefinite proportions. This in itself is sufficient proof that an alloy is a mechanical mixture, or a solution of one metal in another. A very minute proportion of a given metal will most effectually alter the character of another; thus, neither lead nor gold are brittle, but 0.25% of lead will make the more precious metal very brittle. and all the metals usually employed to produce hard copper alloys are soft. In producing an alloy it is necessary that the metals be intimately mixed to secure a satisfactory result, and it is advisable to cast the metal into ingots, breaking them up as required for remelting.

The most important of the non-ferrous alloys are those of copper with other metals, but over fifty alloyed metals are in commercial use.

THE COMMON NON-FERROUS ALLOYS.

Name.	Copper.	Zinc.	Tin.	Lead.	Antimony.	Bismuth.	Properties.
Best Brass ..	70	30					Good malleability.
Muntz Metal (Yellow Brass)	60	40	1*				Resists corrosion.
Delta Metal ..	56	40-42	Iron added up to 1%				
Bronze (Gun metal)	90		10				Very tough.
Pewter (Plate) ..	2		88		8	2	
,, (Common)			82	18			
Britannia Metal ..	2		90		8		Takes a high polish.
Type Metal ..		15	15	65	5		Expands slightly in the mould when solidifying
Babbit's Metal ..	3		90		7		Low co-efficients of friction. Used for bushes and linings of bearings.
White Metal ..	8		84		8		

* When tin is added called Naval Brass.

Alloys of copper and tin are termed " bronzes."

Those of copper and zinc " brasses."

And those of copper, tin, and antimony " white metals."

FLATTENING SHEET METAL.

Without consideration of the causes responsible for the buckling of sheet-metal, a student has a difficult task in attempting to flatten it.

Bent forms of metal may be divided into two groups. In the first are all " bends," and in the second " buckles." Loose metal is the term commonly applied to buckles, but bends are without this quality, and may be said to have no springiness.

Buckling in sheets is due to irregular internal stresses, chiefly due to bad rolling, unequal annealing, careless hammering or inferior metal. These stresses alter the disposition of the constituent atoms, making one part of the plate taut and rigid, and another " loose." The main difficulty in making a plate a plane surface is the dispersion of the buckles, or the equalising of internal stresses.

The effect of hammer or mallet blows on sheet metal is always to extend, never to contract the metal, consequently to remove a bulge, a number of outward blows should be given in a circle round the raised part. By repeating the process carefully a tensile stress is exerted in all directions outwards, and ultimately the buckled part becomes flat. The edges of the plate in turn may curl up slightly, but these can be set down by hammering on each face alternately. Platers become extremely skilful in straightening boiler and ships' plates. A large plate, often distorted as much as six inches, is laid on an iron bed, the plater taps with a lath the places to be hammered, and blows are given with sledge hammers. The plate can be made so flat that when raised at one end and suddenly released, the cushion of air beneath allows it to drop down with little noise.

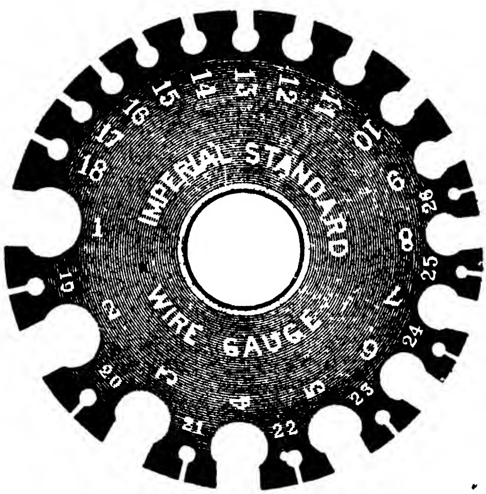


FIG. 56

GAUGING SHEETMETAL AND WIRE.

Graduated rules cannot be successfully used either directly or with the aid of callipers for measuring the thickness of a sheet of metal, or the diameter of a thin wire. To determine these accurately, " contact " measurement is the only system possible. Contact instruments are known by the name of Wire and Plate Gauges. Unfortunately there are too many gauges, and from their multiplicity arises confusion amongst those outside the metal working trades.

In spite of all efforts to bring about standardisation, first advocated by Sir Joseph Whitworth in 1857, we have still a Birmingham Wire Gauge, Zinc Gauge, Lead Gauge, Lancashire Gauge, Music Wire Gauge, and a Needle Wire Gauge, to mention but a few.

IMPERIAL STANDARD.

SIZES OF THE NUMBERS OF THE IMPERIAL STANDARD WIRE GAUGES WITH DECIMAL EQUIVALENTS, WHICH ARE STAMPED ON THE BACK OF EACH GAUGE.

No. of Wire Gauge.	Size of each No. in Decimal Parts of an Inch.	No. of Wire Gauge.	Size of each No. in Decimal Parts of an Inch.
1	.300	13	.092
2	.276	14	.080
3	.252	15	.072
4	.232	16	.064
5	.212	17	.056
6	.192	18	.048
7	.176	19	.040
8	.160	20	.036
9	.144	21	.032
10	.128	22	.028
11	.116	23	.024
12	.104	24	.022

The Imperial Standard Wire Gauge is the one now commonly used for gauging brass, copper, iron, tinplate, etc. This gauge was legalised by an Order in Council in August, 1883, and owes its origin to the fact that before that date there was no standard measure for wire or sheetmetal. The Board of Trade attached the letters B.W.G. to this Standard Gauge, but have since discontinued the use of these letters, and now distinctly state there is no Standard of the Birmingham Wire Gauge. As will be seen in the illustration, parallel-side notches of various widths are cut around the edge of a steel plate $\frac{1}{8}$ of an inch in thickness, each space being distinguished by a numeral. The numbers in Fig. 56 range from No. 1 to No. 26. The number or "gauge" of a sheet or wire is ascertained by testing which notch is just sufficiently wide to allow the metal to slide in

BOOKS FOR REFERENCE.

"Practical Sheet and Plate Metalwork," by E. A. Atkins. Messrs. Pitman & Sons, Ltd.

"Metal Plate Work," by C. T. Millis. Messrs. Spon, Ltd.

"Tin-Plate Working," by R. H. Clarke. The Technical Publishing Co.

CHAPTER XII.

Lathes and Lathe Work.

FROM the point of view of interest, lathework holds a unique place among metalworking operations. The continuous curling shaving from a slowly rotating piece of mild steel, or the yellow shower of particles from a rapidly spinning cylinder of brass, under the action of well-set tools, never fails to excite the wonder of beginners, and there is a fascination attached to bright machined surfaces which stimulates the craft-pride of experienced turners.

The need for some device in which material could be rotated about a geometrical axis, whilst a cutting tool travelled along and against it, must have been felt by very early craftsmen, for the origin of the lathe is lost in antiquity. The machine as we know it to-day is the result of a slow evolutionary process, which had its germ no doubt in the potter's wheel.

Early European lathes were not continuous in their action, being similar in this respect to the pole lathe still being used extensively in Eastern Countries to-day. A certain number of revolutions are made in a clockwise direction during which the tool cuts, then the motion is reversed, and the tool stands idle for the same number of turns. Truly, to us, a mechanical people, it betrays an absurd lack of enterprise, when, by a simple application of crank and connecting rod, the machine could be made to perform twice the useful work with the same effort.

The modern metalwork lathe is a universal machine. All classes of work can be performed in it, which, a few years ago, required separate machines; but for handicraft purposes the choice of a lathe should be influenced by the following considerations :—

I. Simplicity of design.

II. Rigid construction and stability

III. Ease of handling.

IV. Efficient drive with low power.

V. Economy of upkeep.

There are many excellent makes of machines which possess all these essentials. Those illustrated in Fig. 57 are types particularly suitable for instructional requirements.

If two or more lathes are being installed, one should be of the simple type '*A*,' Fig. 57. This is a brass-finisher's lathe, easily understood and controlled by a young student commencing metal turning. Hand-turning would be performed in this lathe, and useful experience and skill acquired in the management of a machine, before an attempt was made to operate a compound one with gears, feed motions, etc. A suitable size is 3½″ or 4″ centre, with length of bed 4′ 0″.

Sliding, surfacing and screw-cutting lathes, the parts of which will be described later, are shown in the same figure. '*D*' is the well-known 3½″ centre "Drummond," very suitable for light work, and '*B*,' and '*C*' well designed machines adaptable for all kinds of turning. The length of bed recommended is 4′ 6″, and height of centres 4½″ and 5″.

All these lathes are fitted with treadle drives (see '*B*,' for rooms not equipped with power, but in the planning of the metalwork room (see Figs. 1 and 2) provision was made for driving by means of electrical energy, and two countershafts running at 280 revs. per minute are shown in position over the lathes.

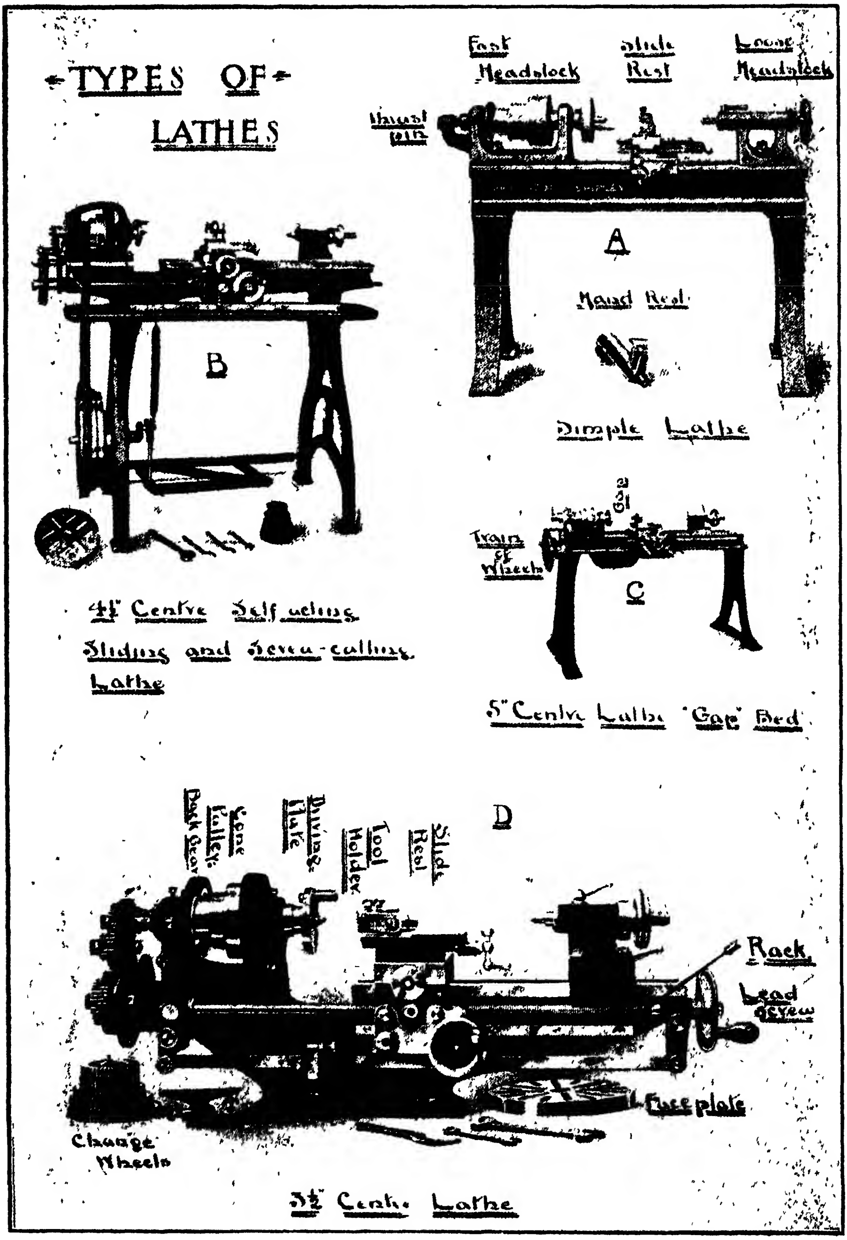


FIG. 57.

The lathe work described hereafter has been performed on similar power driven lathes. It can however be carried out equally well, as regards the finished product, on treadle machines, but a much greater expenditure of human energy and time will be necessary.

The lathe affords an excellent opportunity for demonstrating the "velocity ratio," "mechanical advantage" and "efficiency" of machines, and these mechanical principles, as well as the elements of construction, should be thoroughly understood by all students, if the full value of a training in machine work is to be obtained.

SPEED VARIATION.

The transition from foot to power lathes introduces the problem of driving at variable speeds to suit the diameter of the work, and the nature of the material which is being turned. The high velocity of the belt to the main shaft must be considerably reduced before being communicated to the work, and this is partially effected by means of a countershaft on which is keyed a speed cone (see Fig. 58), similar in every respect, but reversed in position, to the one on the lathe mandrel. The steps on each cone are in "geometrical progression," *i.e.*, each step represents the same percentage of change of speed, whilst the belt length is constant throughout the range.

The change of belt velocity, brought about by speed cones and proper pulleys on the main and countershafts, enables us to vary the "cutting speed," to suit metals having different properties and diameters. The method of setting out a speed cone is illustrated at Fig. 58. The inside of the cone is hollow, the rim '*R*' being connected with the boss '*B*' by a circular plate of metal '*P*.' The ends of this cone are left open, and the boss is fixed to the shaft by a sunk key. The diameter of the middle speed is obtained by drawing a line *a b*, from one edge of the lowest step to the corresponding edge of the highest one. Where this line intersects the edge of the middle step draw a horizontal line. This line represents the rim of the intermediate "speed." All the steps are shown "crowned" to a radius equal to that of the largest step.

The diameters of the intermediate steps may also be determined by the following formula :—

Let D = diameter of large speed.
d = „ small „
N = number of steps.

Then $\dfrac{D-d}{N-1}$ = increase in diameter per speed.

Example.—Suppose in Fig. 58 $D = 8''$ and $d = 5''$.

$$\frac{8-5}{3-1} = \frac{3}{2} = 1\tfrac{1}{2}$$

Diameters are $5''$. $5+1\tfrac{1}{2} = 6\tfrac{1}{2}''$. $6\tfrac{1}{2}+1\tfrac{1}{2} = 8''$.

A further example of applied mathematics is afforded by checking the diameters of the intermediate pulleys by logarithms, using the following rule :—

I. Subtract the log of the lowest speed from that of the highest.
II. Divide the difference by the number of speeds in the range less one.
III. Subtract the quotient from the log of the highest speed.
IV. The difference is the log of the next lowest speed.

By repeating this calculation the required number of times, the list of speeds in the range is obtained.

Example.—Assume on a four stepped cone the highest speed is 400 revs. and the lowest 100.

Log 400	=	2.6021	Log of highest speed.
„ 100	=	2.0000	„ lowest „
		.6021	Difference.

$$\frac{.6021}{3} \quad \text{No. of speeds less one} = .2007 \text{ Quotient.}$$

2.6021		Log of highest speed.
.2007		
2.4014	=	Log 252. Next highest speed.
.2007		
2.2007	=	Log 158. Next highest speed.
.2007		
2.0000	=	Log 100. Lowest speed.

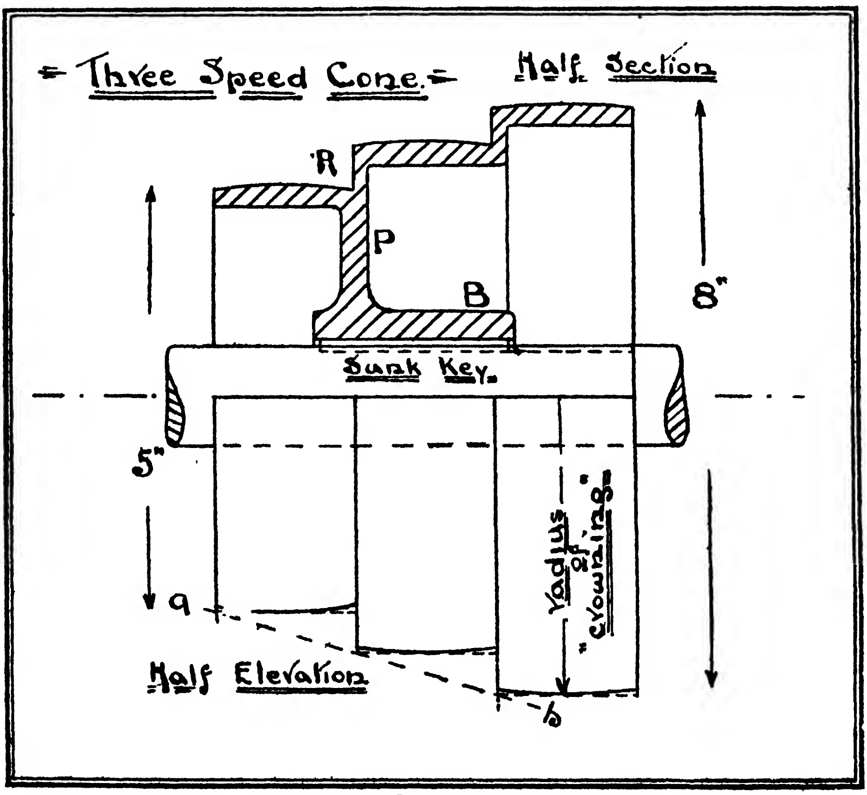


FIG. 58.

THE HEADSTOCKS.

Each of the lathes illustrated in Fig. 57 is fitted with two headstocks, viz., a fast one, fixed at the right-hand end of the lathe bed, and a loose one, which slides along the bed to any position required.

PARALLEL BEARINGS.

Fig. 59 shows the elevation and part plan of a fast headstock similar to that on lathe ' C,' Fig. 57. The spindle or mandrel which carries the cone and the " live centre " is shown in this case to run in parallel brass, or gunmetal bearings. The " brasses " are split horizontally, and the upper halves held down by cast iron caps which fit on the standards of the headstocks, being held there by studs and nuts.

The end pressure exerted by the tool on the work when traversing, is partly borne by the face of the right hand pair of brasses. The greater portion of this axial pressure should, however, be borne at the left hand end of the mandrel, and in the plan are seen two pillar studs bolted to the left hand standard of the headstock, at the level of the mandrel centre. Across the studs is a bridge piece which carries a hardened steel thrust pin. The pin has its end screwed with a fine thread, and is clamped by two nuts, one on each side of the bridge. By adjusting the nuts, the pin can be moved forward or backward just enough to allow the collar on the front end of the mandrel to touch the brasses without allowing much pressure to be borne by them.

The thrust-pin must be constantly lubricated when the lathe is running.

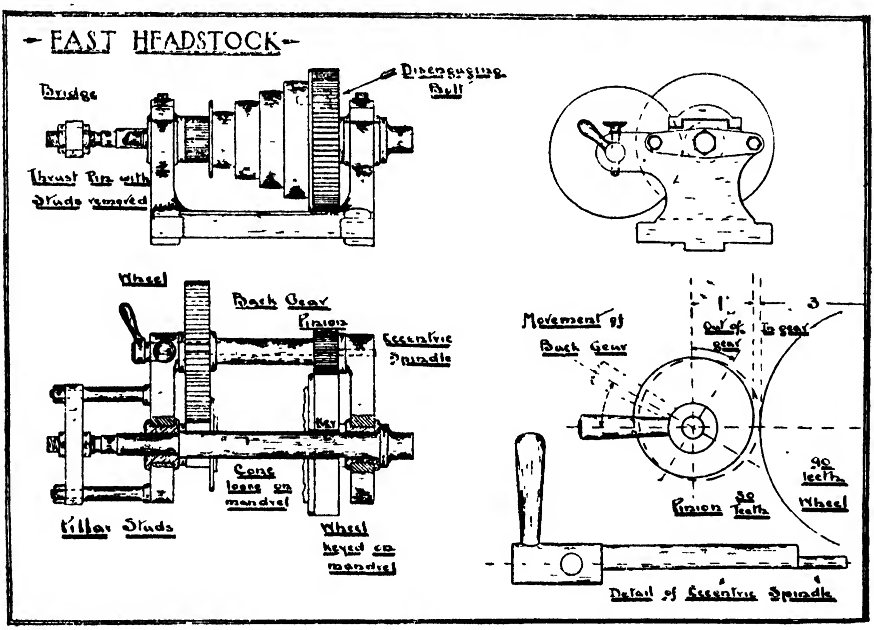


FIG. 59.

CONICAL BEARINGS.

Another method of mounting the mandrel is shown in Fig. 60. The front end has a cone turned on it which fits into a solid brass or steel bush, whilst the back end, which is turned cylindrically, also fits into a conical bush oppositely inclined to the front one.

To bring about adjustment as wear proceeds, it must be possible to bring the two cones nearer to each other. The one is therefore made part of the mandrel, and the other a sliding fit on the back end. A fine screw thread is cut on this end, and on the screw are two nuts, by means of which the sliding cone is forced forward until the two cones fit snugly into their bearings.

As in the case of parallel bearings the main portion of the end pressure is borne by the thrust pin, but a small amount of it is distributed over the conical surface of the front bush.

Opinion is divided as to the relative merits of the two constructions. In actual running efficiency there seems to be little difference. Conical bearings are less costly to produce, and are therefore preferred for small lathes, but when refitting becomes necessary, and bushes have to be re-bored and scraped, these repairs are much more readily performed on split parallel brasses than on conical ones. This, perhaps, is the only reason why parallel bushes in capped headstocks are fitted in large lathes.

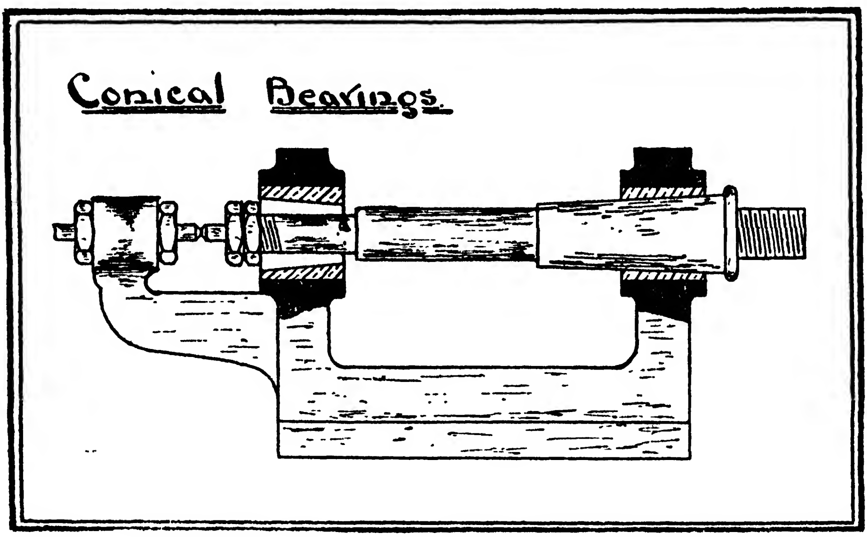


FIG. 60

BACK OR DOUBLE GEAR.

Upon the mandrel of the fast headstock is mounted the stepped cone pulley, and for a constant speed of the countershaft as many speeds may be obtained as there are steps on the cone. In Fig. 59 there are four. If these variations are considered sufficient for the purposes for which the lathe is to be used, the cone is keyed to the mandrel and drives it directly. The lathe in this case is said to be "single geared."

But the number of speed variations may be doubled by adding toothed gearing (see Fig. 59) called "back gearing," and a lathe so fitted is described as being "double geared." The cone is not keyed to the mandrel, but revolves

freely on it, and on its small end is fastened a spur pinion. The pinion is frequently part of the same casting. At the other end of the cone, but free from it, is a large spur wheel securely keyed to the mandrel (see Fig. 59).

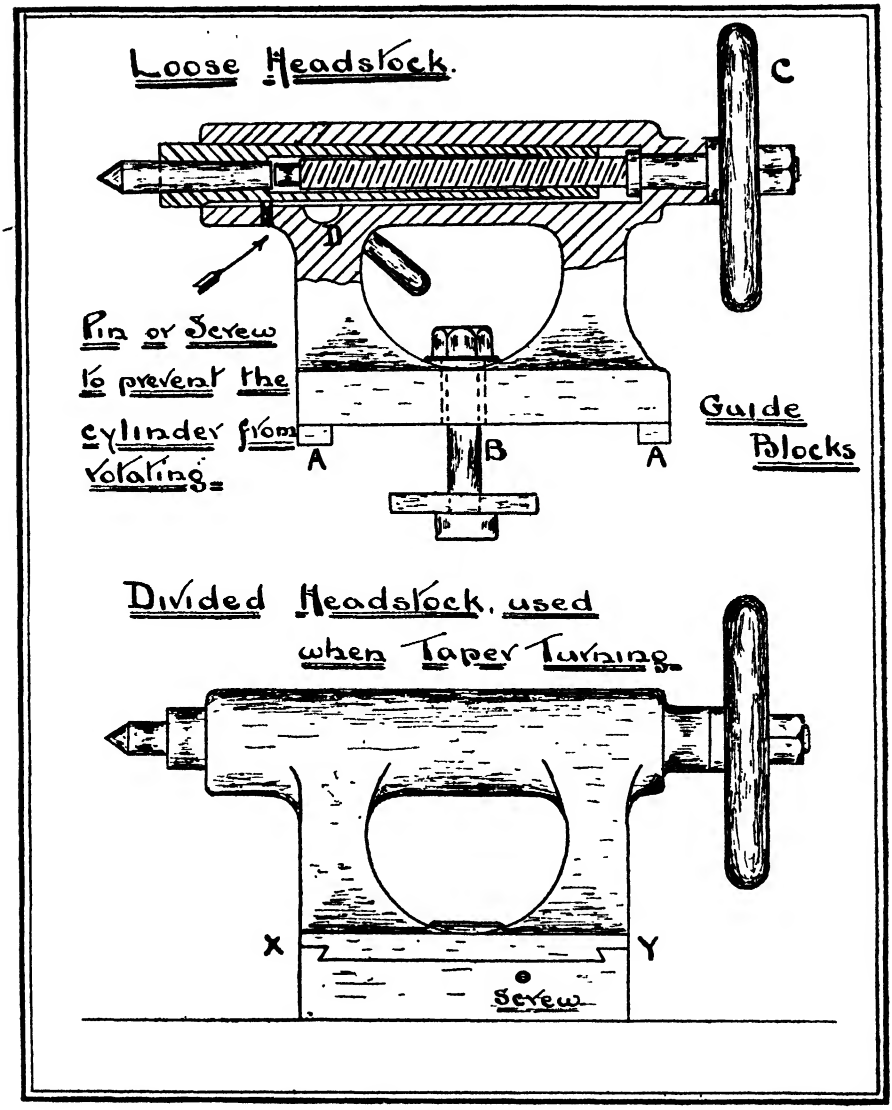


FIG. 61.

A wheel and pinion of corresponding sizes are carried on a back shaft mounted in bearings parallel to the main bearings of the mandrel. The back gear can be made to engage or disengage with the spur wheels on the mandrel, either by means of an eccentric or a sliding motion.

The bolt shown in elevation Fig. 59, must be withdrawn or lowered so that it does not engage with the cone when the back gear is to be used. Motion is transmitted from the mandrel pinion to the back shaft wheel. This wheel being fixed to the same shaft as the back pinion causes it to revolve also, and drive the mandrel wheel, which, in turn, being keyed to the mandrel causes revolution.

The reduction in speed depends upon the relative proportion of wheels and pinions, but an average mandrel speed is 1/9th of the speed ungeared. Fig. 59 illustrates this diagrammatically. The mandrel pinion, revolving at, say, 180 revs. per minute, drives the back wheel at 60 revs. as its diameter is three times as great. The back pinion also revolves at 60 revs. and turns the mandrel wheel 20 times, or only 1/9th the pulley speed. Students of Mechanics will observe that the apparent loss of useful energy by this reduction is compensated for by the increased turning effort on the mandrel. By the leverage of the wheels this is amplified exactly nine times.

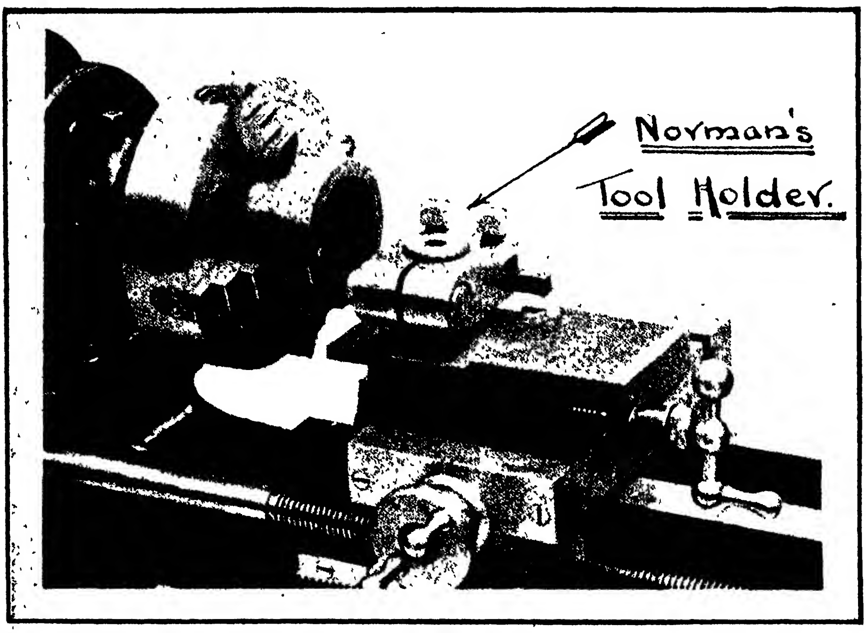


FIG. 62.

MOVING HEADSTOCKS called Tailstocks, or Back Poppet Heads are shown in Fig. 61. They carry the "dead centre" which gives the necessary support to the right hand end of the work. It is very important that this back centre, as it is often called, shall always be in alignment with the axis of the mandrel, whilst the distance between the centres must admit of easy and rapid adjustment. The headstock is therefore made movable along the bed, its motion being confined to the proper line by the blocks A A sliding along a groove in the bed, whilst the nut, bolt, and plate '*B*' enable it to be securely clamped in any desired position. Further adjustment is brought about by turning the hand

wheel ' *C*,' to which is attached a spindle having a left hand square thread screw. The spindle operates a cylinder, which slides backward and forward in the barrel of the casting. The cylinder has a tapered hole in its end, and in this fits the centre.

Any tendency on the part of the sliding cylinder to revolve with the spindle is resisted by a small key running in a keyway cut on its under side, or a pin, with its end filed like a small key, can be screwed into the casting to fulfil the same purpose.

To prevent the spindle from " slacking back " by the vibration due to the cutting action of the tool on the work, a locking bolt ' *D* ' is fitted in the headstock, and made to work slightly eccentrically. By means of a handle the bolt can be turned to bind against the cylinder and lock it securely.

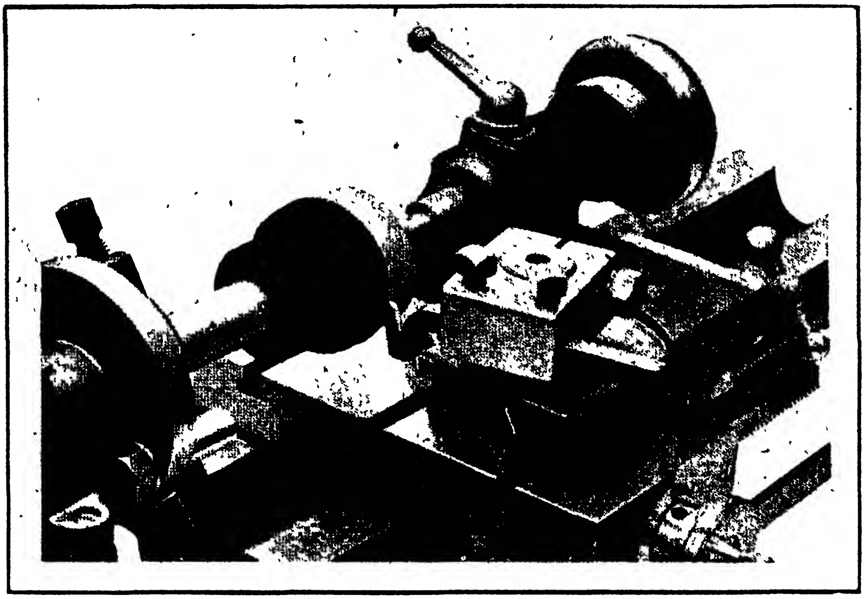


FIG 63.

TOOL RESTS.

A simple tool rest for hand turning is seen under lathe ' *A* ' in Fig. 57. A small metal table on a vertical spindle can be raised or lowered to bring the cutting edge of the tool to the height of the lathe centres. On this table the heel of the tool is pressed, and sweeping or sliding cuts given as the nature of the work demands. A " rest " in which the tool is fixed, and which has motions parallel to, and at right angles to the axis of the work is a much more complicated mechanism.

One is shown in position on the bed of lathe ' *A* ' (Fig. 57). It consists of machined plates fitted very accurately together in the manner illustrated. The top plate carries a tool post in which the tool is firmly clamped. The plates slide over each other when operated by the screws, and the rest is therefore called a " slide rest." Also, because the motion given to the tool is compounded it is known as a " compound slide rest."

The movement of the tool along the work in this type of rest is of course a hand operation. The slide rests of screwcutting lathes have additional mechanism, as some arrangement must be made for engaging and disengaging with the lead screw.

To the bottom plate of the slide rest is attached an "apron" piece which carries a half nut and operating handles. When the tool has come to the end of a cut, the half nut can be disengaged and the saddle wound back quickly by means of a rack, fixed to the bed of the lathe, and a pinion attached to the apron (see '*D*,' Fig. 57 and Figs. 62 and 63).

TURNING OPERATIONS.

The lathe work of the handicraft room may be classified under the following headings :—

I. Turning between, or in the line of the lathe centres.

II. Surfacing or facing in chucks, *e.g.*, producing a plane surface at right angles to the line of the centres.

III. Taper-turning.

IV. Boring.

V. Screw-cutting.

CENTERING.

There are a number of different methods of determining the centres of the ends of spindles before mounting for turning between lathe centres.

Fig. 66 illustrates four of them.

(*a*) By means of a bell punch. This is a convenient method if such a tool is to hand, and the necessary precaution has been taken to make the end of the work at right angles to the axis.

(*b*) By the use of vee blocks and a surface gauge. The end of the work is chalked or painted, and the point of the gauge placed approximately in the centre. If the work is revolved slowly, a small circle will be drawn on the end. The exact centre can then be estimated and marked with a dot punch.

(*c*) By making use of the rule, "Two intersecting diameters determine the centre of a circle," and using a centre square to draw them. At the point of intersection punch lightly with a dot punch.

The bar must be round if this method is to be applied satisfactorily.

(*d*) By means of odd-leg, jenny, or hermaphrodite calipers. The curved leg of the tool is held against the side of the rod, and an arc is described on the chalked end with the straight leg. Moving the curved leg through a right angle each time, the operation is repeated thrice. A small four sided figure will be formed by the four arcs, and the centre may be determined with a fair degree of accuracy.

In all these methods the centres are only lightly indicated with a tap on the dot punch, the indent being made deeper afterwards with a centre punch. After centres have been located on both ends, their accuracy may be tested by placing the work between the lathe centres, and rotating it rapidly by drawing the hand quickly across it. Holding a piece of chalk close to the work as it spins round, a mark will be made on the "high" side if the centres are not in alignment. To correct this, the centres must be "drawn over" by the method illustrated in Fig. 14.

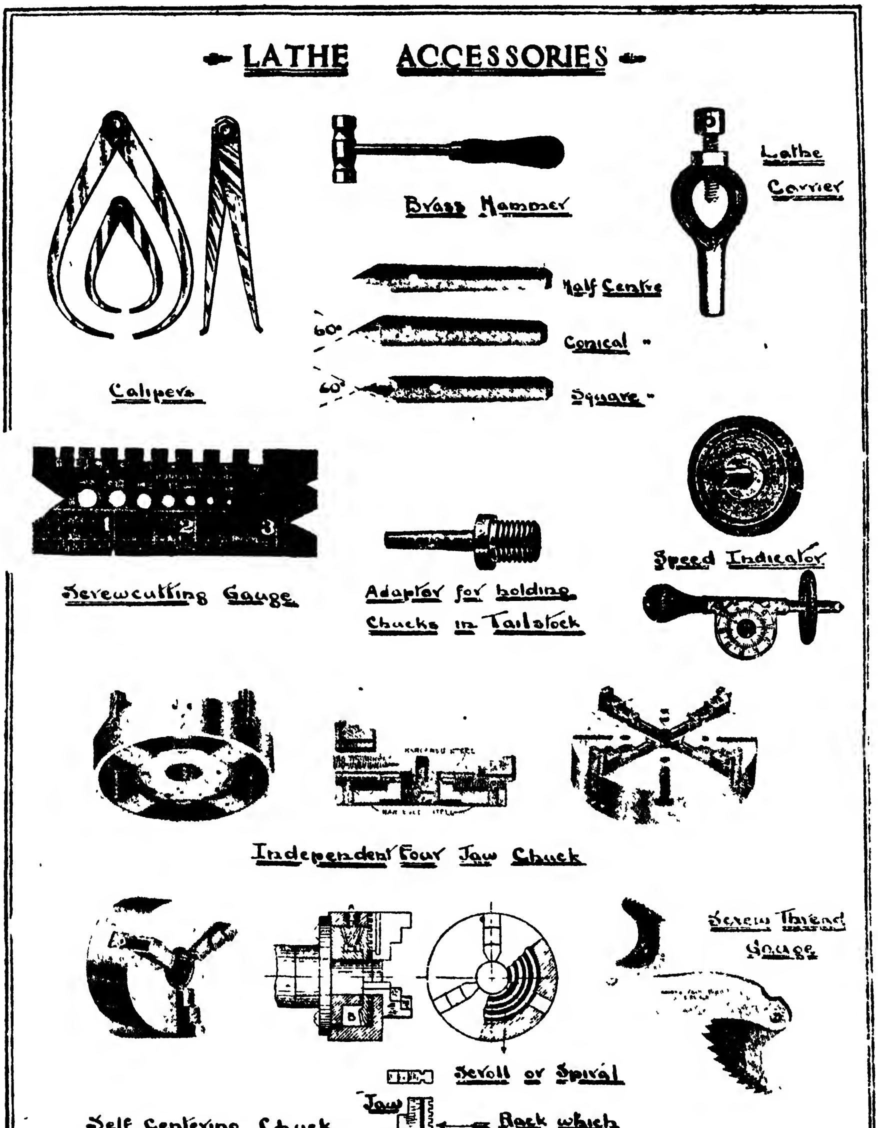


FIG. 64.

LATHE CENTRES.

The question is frequently raised "What angle is the most suitable for lathe centres?" To answer it satisfactorily we must consider the pressures acting on these points of support. The pressure, exerted on the work by the tool when cutting, has two components:—one perpendicular to the axis, due to the rotation of the work, and the other parallel to the axis, due to the traversing feed. These pressures are transmitted to the centres, and although the bearing area is very small, their wedge-like action tends to crush the material round the centre hole in the work.

In soft material this crushing is very appreciable, and the work hangs loose between the centres, making it necessary for them to be tightened up before a true cylinder can be turned.

The crushing and wear of the material in the centre holes are produced by both the components of the pressure. The perpendicular force will be better resisted the more acute is the angle of the steel centre, but, at the same time, the material will be less capable of resisting axial pressure, because the surface will be very oblique to the direction of the thrust, and the conical steel point will penetrate into the metal like a wedge. Any change therefore, in the angle of the cone is advantageous with regard to one pressure component, but disadvantageous with reference to the other. The "best" angle is one of

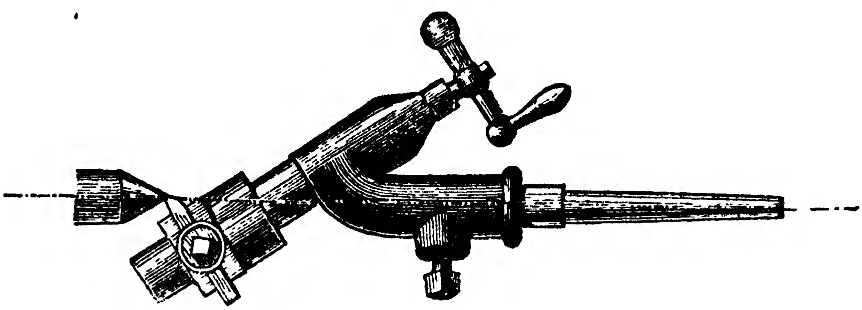


FIG. 65.

compromise, and centres are now generally ground to 60°. Fig. 64 shows three centres ground at their apices to angles of 60°, and Fig. 65 a device for turning and truing the centres of lathes when in position. It will be seen that the tool is really a small slide rest fixed at the required angle, and mounted in the tail stock. The cutter is adjusted to the exact line of centres by turning the tool post slightly in one direction or the other on the barrel which supports it, until the cutting edge is exactly on the centre line. It is then fixed by tightening the set screw at the bottom of the slide. The depth of cut is regulated by moving the tail spindle in or out.

None of the pressure should be borne by the extreme point of the centre. The volume of metal here is so small, that, when used in the tail stock end, the centre would quickly become overheated, and the temper be withdrawn. In order to avoid this, it is necessary to drill a small hole about ¼″ deep in the end of the work, and countersink it to the correct angle to receive the centre. Not only does this make a better seating for the centre, but the hole forms a small reservoir for oil, which surrounds and lubricates the point. Fig. 66 shows a combination drilling and countersinking drill, "Slocum" pattern, and a section of a spindle drilled with it, and ready for mounting.

SQUARE CENTRE.

This form of centre (Figs. 64 and 66) is frequently used for truing and enlarging centre holes in the ends of rods and similar work. The end is ground to form a square pyramid, and then hardened and tempered.

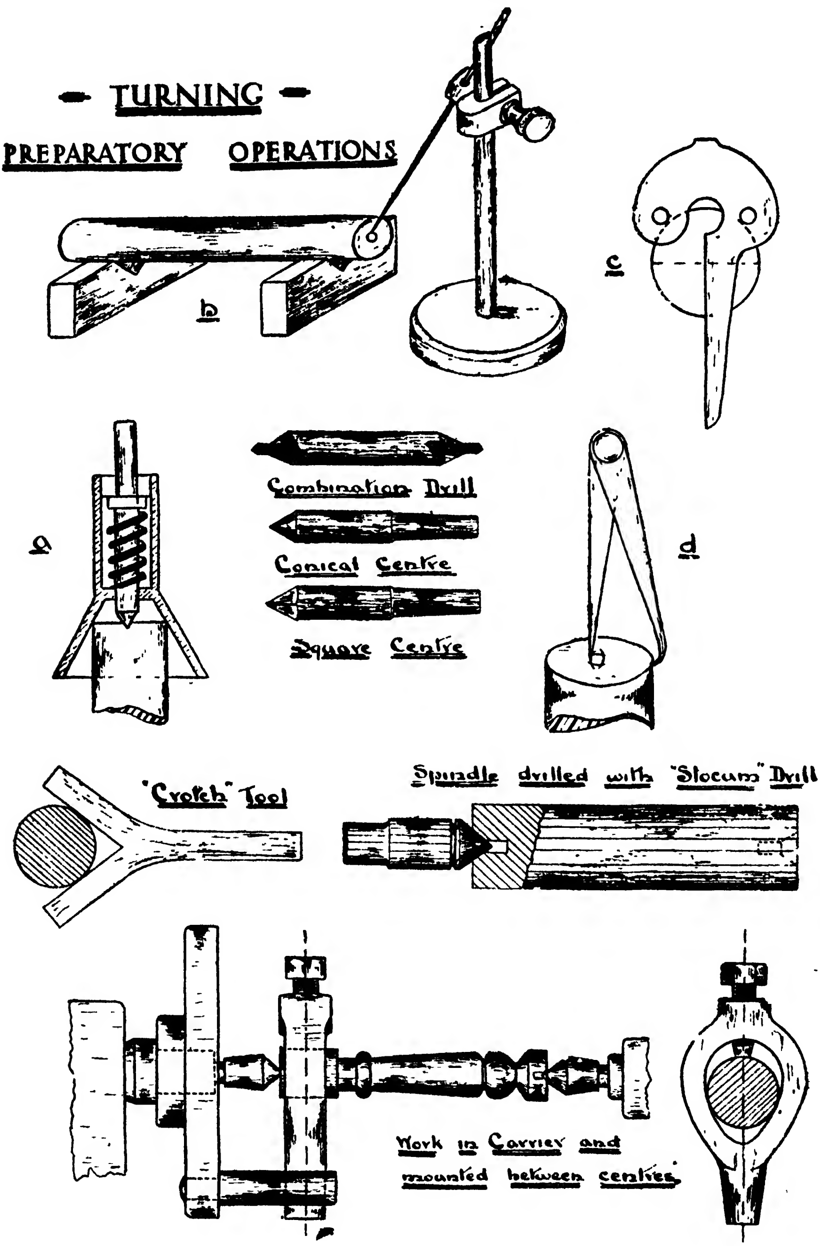


FIG. 66.

When the work has been centered, and set running between the "live" centre and the square centre in the tail stock, any inaccuracy in the centering may be corrected by pressing a bar, clamped in the slide rest, against the work, which in turn is pressed against the square centre. The sharp edges enlarge and true the hole, making it concentric with the circumference of the work. Having got one end true, it might be necessary to reverse and repeat the operation. A forked bar (Fig. 66), called a "crotch" tool, is the most effective for this purpose.

When the work is running truly the square centre is taken out, and changed for a conical one.

CARRIERS.

The work is caused to rotate against the pressure of the tool by fixing a lathe carrier on one end. The blank end of the carrier (Figs. 64 and 66) rests against a projecting pin in the driving plate, which is screwed on the mandrel and is carried round with it (see Fig. 66).

HAND TURNING.

Whilst turning may be regarded as being the most mechanical of all the processes practised in the metalwork room, considerable demands are made on manual dexterity and intelligence, if work of a high standard of finish and accuracy is to be accomplished.

It might be argued that preliminary practice in wood turning is of very little help to a student in turning metal, because, not only are the properties of the materials so entirely different, but the manner of presentation of the tool to the work is also apparently different. When turning wood, for instance, the chisel is invariably pointed upward on the rest so that the wedge shaped edge may take a skimming cut, but, if using any of the hand tools (Fig. 67) for shaping metal, the heel of the tool would be pressed firmly on the table of the rest with the blade pointing downward.

The presentation of cutting edges to work being machined will be discussed later; it is only necessary here to say that if the theory and action of cutting wedges has been carefully taught and demonstrated, students will approach any turning problems well equipped mentally, and will confidently apply the mechanical principles learned, to any material.

The natural progression is from wood-turning to hand-turning in soft and homogeneous metal, brass being particularly suitable, and there are two considerations that cause the direct hand guidance of the tool to be more instructional and educational at this stage than mechanical guidance.

The first is, that in consequence of the high cutting speed (for brass of say 1" diameter this should be as high as the lathe is capable of being driven), and of the softness of the material, the work being turned is shaped very quickly. The successive changes of position, and direction of the tool feed motion, follow each other rapidly, keeping the student's attention rivetted on the job, and his interest attuned to a high pitch.

Secondly, hand-turned projects generally take the form of handles, terminals, rings, etc., in all of which, pleasing proportion and shape is of more importance than a high degree of accuracy. Curves play a considerable part in the design, and these can only be swept out by hand tools, the direction of the cutting edge being constantly changed as the contour of the work demands. Moreover each piece of turnery can be completed in a comparatively short time, enabling several students to use the lathe whilst the points emphasized in the demonstration lesson are fresh in mind.

There is a " handiness " in direct hand guidance of a turning tool which is lacking in mechanical guidance, but the latter makes for greater accuracy. The suggestions shown in Fig. 68, illustrate the type of work a group commencing turning might be expected to attempt.

HAND TURNING TOOLS.

The set of tools illustrated in Fig. 67 is the minimum required for each student. Many other shapes may be obtained, but as special need for these arises they can be forged from old files, and tempered to suit the material being cut.

Of those illustrated, No. 1, a graver, No. 2, a router, No. 3, a parting tool, and No. 4, a flat tool, are the tools most generally used.

(*a*) THE GRAVER is a bar of tool steel about $\frac{5}{16}''$ square. All the flats are ground smooth, and cutting edges are formed by grinding off the end diagonally. The angle made by the diamond shaped end with the shank varies from 55° to 70°.

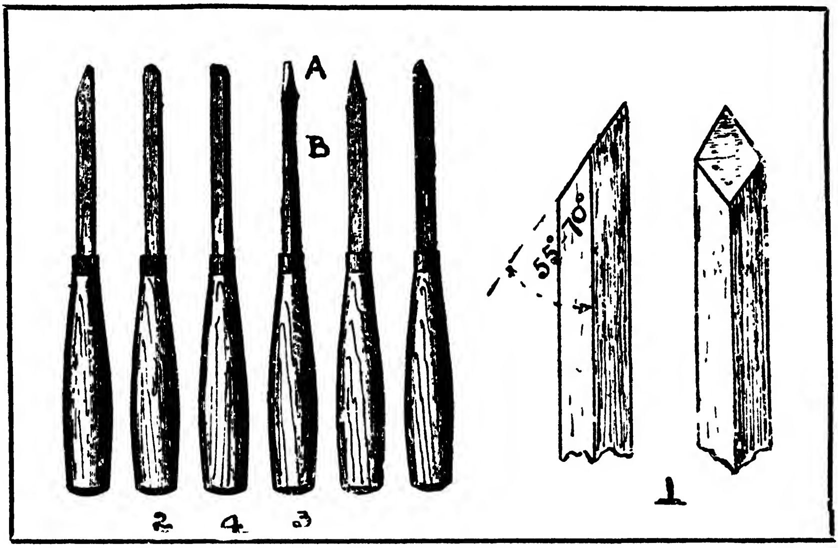


FIG. 67.—HAND TOOLS.

In use, the tool is firmly pressed on to the tool rest with the left hand, and by a sweep of the handle to the right, the point is made to cut, the operation being assisted by turning the graver slightly over. When the handle is so far over that the tool is disengaged, the graver is moved along the rest, and the process repeated.

(*b*) and (*c*) Work roughed out by this means will be irregular as regards smoothness of surface, but the concentric truth will be correct. To give shape and finish, the FLAT TOOL and ROUTER are used. These tools are applied end-on to the work, cutting away the ridges and leaving the surfaces smooth, so smooth and bright in fact, that if the cutting edges are correctly ground, only a rub with a piece of emery cloth wrapped round a suitable holder is required to complete the job.

The use of files is sometimes advocated for the finishing of turned work, but the craftsman regards their use as being very amateurish, knowing that no surface can be obtained by their employment comparable with that left from a well set and skilfully handled cutting tool.

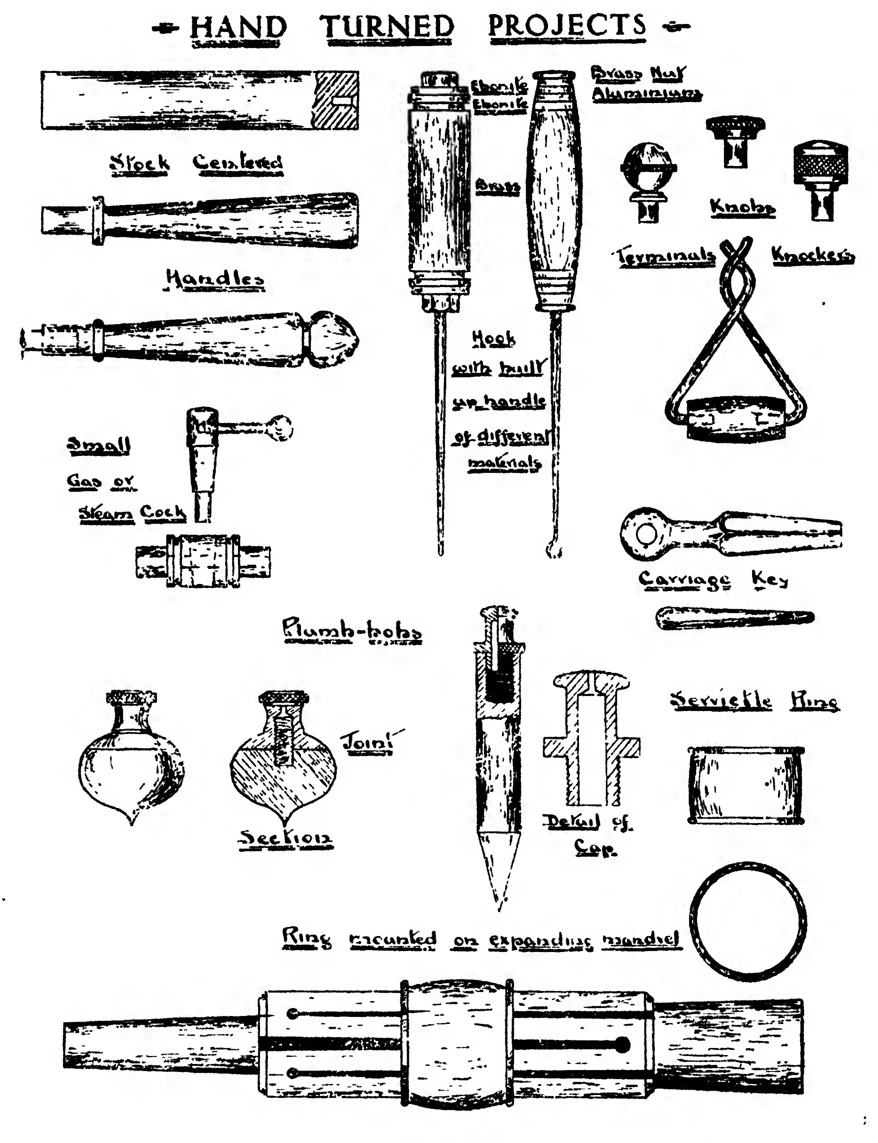


FIG. 68.

Modern grinding machinery will produce bright cylindrical surfaces to a much greater degree of accuracy than is possible in turning practice, but this, the only abrasive process that can be considered superior to lathe work, is outside the scope of school metal work.

Turned brass should never be touched with emery if a bright lustrous surface is to be retained.

(*d*) Finally to cut off the material to the exact length, a PARTING TOOL is used. It will be noticed that the blade is ground thinner at '*B*,' behind

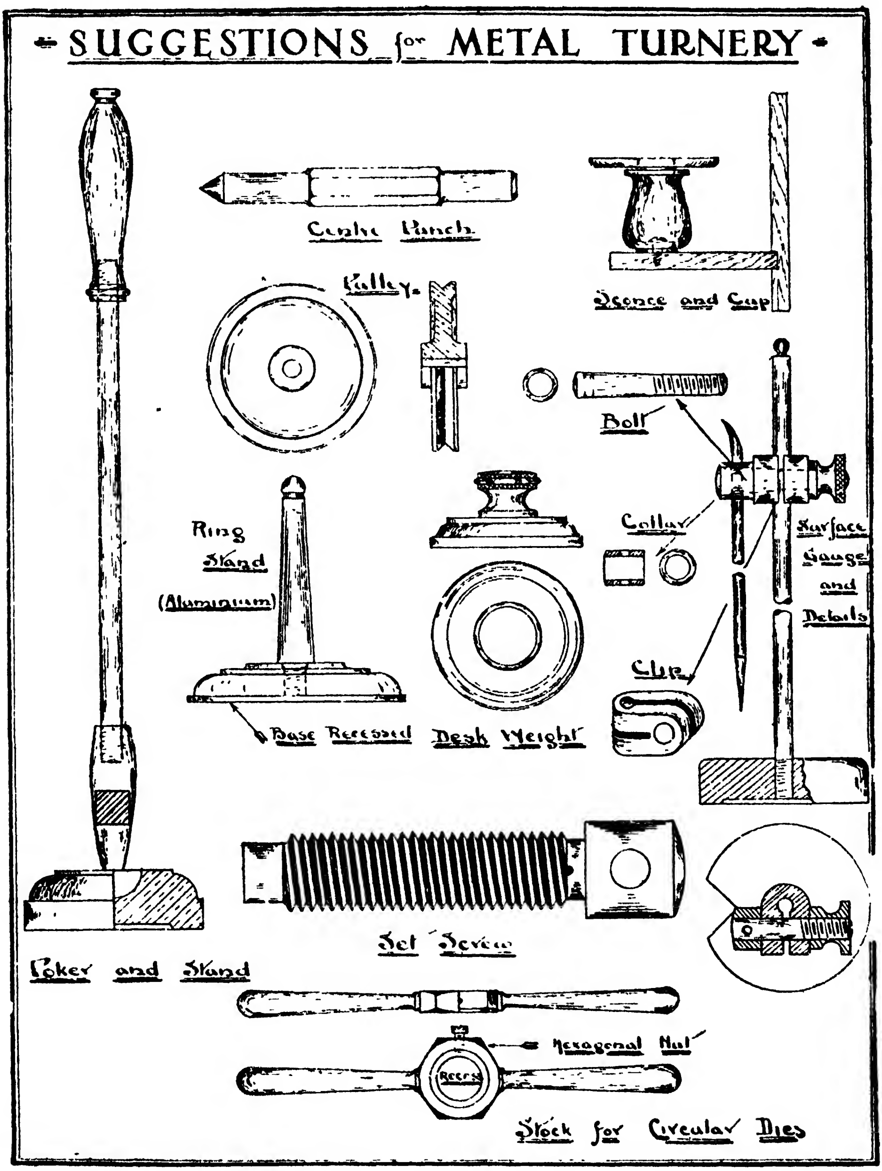


FIG. 69.

the cutting edge '*A*' (Fig. 67), in order to give clearance and allow the tool to cut into the metal freely. There is a tendency in "parting off" for the work

to " crowd " on to the tool just at the moment of severence, and be bent or disfigured. To avoid this it is advisable, with important work, to cut in with the parting tool to the safety limit, and finish the cut with a hack saw.

CUTTING ACTION OF LATHE TOOLS.

No tools require more care and attention than do those used for machining metal. Good service can be obtained from most hand tools for either wood or metal-working, even if the cutting angle is altered, due to repeated sharpening, provided the edges are kept keen. But keenness of edge, whilst being of great importance, is only one of the factors which make for efficient turning, and unless combined with correct tool shape, can never produce first class work. Every lathe tool has three, sometimes four, angles which affect its cutting action, and in order to form an estimate of what magnitude they should be, it is necessary that some investigation be made, on the part of each student, into the action which takes place when a shaving is removed by a metal cutting tool.

Fig. 70 (*a*) shows a swan's neck or spring tool severing metal from a round bar by a combined shearing and paring action. The first thing that occurs when the tool is pressed against the material is the compression of the metal at '*A*,' immediately above the cutting edge. The layer of material '*B*,' just back from the cutting edge, is subjected to a severe tensile stress, and also a bending action. Separation therefore takes place at the point of maximum tension.

The traverse of the tool causes these actions to be continually repeated. The separated compressed particles accumulate on the tool face, and finally break away (sheared if the top face of the tool is flat), or are removed in the form of a shaving.

TOP FACE CLEARANCE OR "TOP RAKE."

If the tool is ground away on the top face and given what is called " top rake," a wedging action takes place, and the material is removed by the combination of this wedging action (paring) and shearing. It is interesting to note the similarity of the paring action of lathe tools, due to provision of rake, to that of properly ground twist drills (see '*K*,' Fig. 11).

Another effect of top rake is to cause the tool to cut into the work with comparative ease, but there are considerations which limit the amount that can be given. The differences in the textures of metals make the angle '*X*' (Fig. 70) a variable one. Also, the direction of the forces acting on the top face of the tool are at right angles to it (see Fig. 70), and if a tool possessing too much top rake projects a considerable distance from the tool post, any bending of the body of the tool, due to these forces, will tend to draw the cutting edge deeper into the cut.

If the tool were strained equally at all times during the cut, the spring or bending would also be equal, and the cut therefore a smooth one; but, when taking a roughing cut, there is usually more metal to be cut off the work in one place than another; besides which, inequalities in texture cause the tool to spring more when hard places are encountered, and the work is left uneven.

A further limiting factor to top rake is the power absorbed by the friction of the shaving. Reference to (*b*) Fig. 70, shows that the more inclined the top face is, the further the chip slides along the tool before bending and rupture take place.

When turning cast iron and brass, the top rake given to the tool should be very little; for brass the best all round results are obtained with none at all, and many brass turners even prefer a tool with the top face inclined upward from the work (see Fig. 70 '*C*'), having what is termed "negative top rake."

These metals are brittle and "short," and it is not intended to obtain a shaving with the tool, so much as to separate the particles and cause them to fly from the tool point, carrying away the heat as fast as it is generated. Brass particles leave the work with such high velocity that it is dangerous to observe the cut too closely, and it is a good plan to put a split leather washer over the tool, just behind the cutting edge, to deflect them.

ANGLE OF RELIEF OR "BOTTOM RAKE."

The angle that the under surface of the tool makes with a vertical tangent to the work (see '*Y*,' Fig. 70) is termed the "angle of relief," and is commonly referred to by turners as "bottom rake."

It is necessary to grind a tool away in this manner in order to avoid its rubbing against the work surface, thereby causing frictional resistance to the motion of the lathe.

Tools (unless given excessive top rake, when there is an opposite tendency) exert a considerable horizontal pressure on the work, which crushes the material inwards to a small extent. Reaction causes the metal to spring back again immediately below the cutting edge with the result that for a very small distance the surface is inclined outwards from the vertical; the projection is of course very minute, and it is only necessary to grind away very little of the tool front face to give the required clearance (3° to 10°).

CUTTING ANGLE.

Again referring to (*a*), Fig. 70, it will be seen that the solid angle '*Z*' of the tool equals a right angle minus the sum of '*X*' and '*Y*.' The angle '*Z*' is called the "cutting angle," and it becomes less, the greater either top or bottom rake is made. To determine the acuteness of this wedge, or the correct cutting angle for a definite purpose, it is necessary to bear in mind that whilst it is very desirable to have a keen tool, it is also essential to have sufficient metal to support the cutting edge. When cutting cast iron in a lathe the particles are broken away immediately, consequently the cutting angle may be large—70°, but when machining mild steel, the cuttings of which are much more tenacious, and have to be forced off by the point of the tool, a more acute wedge is needed. The most suitable cutting angle in this case being one of 60°—65°.

SIDE RAKE AND CLEARANCE.

In addition to the three angles described, many lathe tools with rounded points, or "round nosed" tools, are given what is termed "side rake," the top face being ground as shown at (*d*), Fig. 70. During the traversing of a heavy cut the actual cutting is done almost wholly by the side of these tools, and it is therefore, quite as necessary to provide side rake, and side clearance, as top rake and front clearance.

A tool without sufficient side rake, not only cuts badly, but also requires considerable force to make it feed forward in its traversing motion.

On the contrary, the angle can be so nicely adjusted that the tool will almost feed itself into the cut, thereby causing little wear in the self-acting feed gear of the lathe.

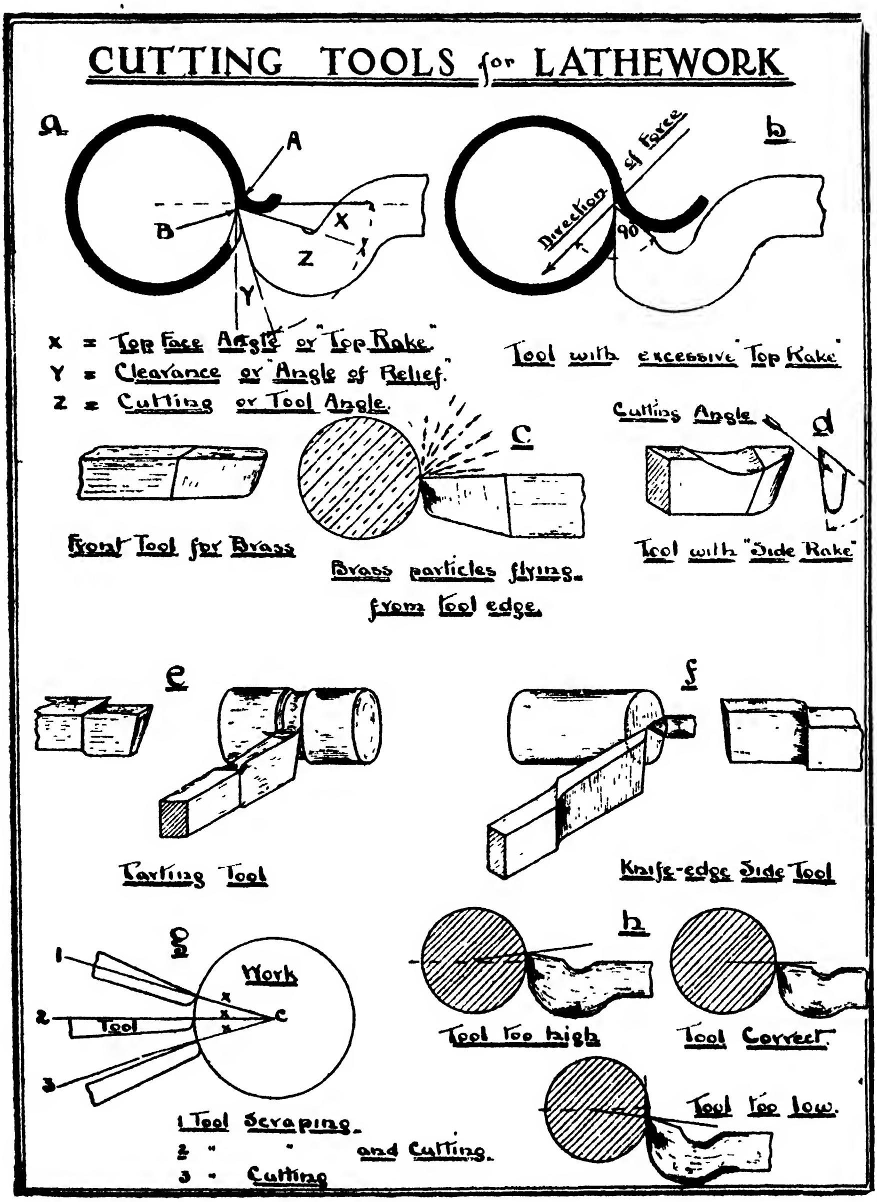


FIG. 70.

Tools so ground are limited to cutting in one direction only, but this is not a disadvantage, because, when using cutting tools, the secret of efficient working is to grind each tool so as to obtain the best possible result from the particular operation for which the tool is intended.

Whilst a tool without side rake is very disadvantageously formed for a deep cut and a traversing motion, it is much used for a light finishing cut. When so shaped it is termed a "front tool."

THE PARTING TOOL.

Fig. 70 (*e*), used for cutting off material, and for making a rectangular recess in the work, is, by reason of its shape, one of the most difficult to handle. Square nosed, with a broad cutting surface, and of necessity slight of body, it is a combination of all the elements which predisposes a tool to spring and dig into the metal.

The tool should never stand out far from the tool post, and should be ground thinner behind the cutting edge, as shown in the figure, to give ample clearance.

When in operation the cutting edge should be freely lubricated.

SIDE TOOL.

For cutting the faces of collars, truing the ends of spindles, and similar work, a tool known as a side or knife tool, Fig. 70 (*f*), must be used. Not much clearance is required on the side face of this tool, keenness being given by the angle of the top face.

GENERALLY ACCEPTED PRINCIPLES.

From the foregoing considerations it will be seen that a lathe tool may be damaged by :—

I. The wear due to friction with the work.

We cannot avoid this, but every turner knows that a blunt tool wears much more rapidly than a keen one, and therefore the friction may be minimised by keeping the tool well ground.

II. Fracture of the tool end.

Making the relief angle too large is conducive to this. The clearance should never be in excess of the amount required.

III. The temper may be drawn from the cutting edge, owing to the heat generated by the power used in cutting.

Some of the heat may be carried away by using lubricants, but the major part must be carried from the cutting edge by conduction.

Up to a point, the greater the top rake, the less the heat generated, but as it is increased, the body of metal able to conduct heat away is reduced, so, in actual practice there is no alternative but to effect a compromise between ease of cutting, and endurance of the cutting edge.

TABLE OF TOOL ANGLES.

Material.	Cutting.	Clearance.	Top Rake.	Side Rake.
Mild Steel	65°	5°	20°—25°	10°—15°
Cast Steel	75°	3°	10°—15°	5°
Cast Iron	70°	10°	10°—15°	5°
Brass	85°	5°	Nil	Nil

CENTRE LINE OF WORK AND CORRECT SETTING.

Even if a tool be ground to correct shape, the method of its presentation to the work determines whether it shall act as a scraping, or a cutting tool. On reference to (*g*) Fig. 70, it will be observed that the angle of the top face of the tool varies in each case with the line '*X*,' drawn from the centre of the work to the point of tool contact. The shapes and angles of the tools are the same in all three cases, but only in the case of No. 3, when the line '*X*' passes outside the body of the tool, can actual cutting take place. This should be borne in mind when mounting tools in tool posts with adjustable seating pieces, which allow of considerable variation in the inclination of the tool to the work.

The setting of a lathe tool to the height of the lathe centre makes a great difference to its cutting powers, especially on work of small diameter, such as is usually met with in the handicraft room.

Fig. 70 (*h*) shows these tools, brought up to the work :—

(*a*) Cutting edge is too high. The work is rubbing on the front of the tool.

(*b*) Cutting edge is too low. The edge is liable to dig in or fracture, owing to excessive stress being brought upon it. The amount of material to be removed when the tool is in this position is indicated by the shaded portion.

(*c*) This tool is in the correct position on the centre line of the work.

TOOL HOLDERS AND CUTTER BARS.

Tools forged from the solid have several disadvantages, *e.g.*, the amount of steel required makes them expensive, and they require frequent reforging and tempering as they are ground away.

Many years ago Messrs. Smith and Coventry introduced the tool-holder, Fig. 71, in which a small piece of tool steel (now high speed steel) can be secured. To-day, there are many improved types of holders, see Fig. 71, and by their use, not only is economy effected in material, but the tool angles are kept constant because the cutter bars, which are generally square or rectangular pieces of steel, are fitted into slots and recesses so cut to give the correct rake and clearance.

FACING WORK IN CHUCKS AND BORING.

In order to traverse a cut at right angles to the lathe axis, it is necessary to grip the work in a chuck which is screwed on to the mandrel end, or, if of too large a diameter, to mount it in some manner on a face plate, which may also be screwed to the mandrel. Examples such as pulleys, base pieces, screw jack bodies, etc. (illustrated in Figs. 69 and 74) are all circular, and small enough to be accommodated in chucks.

Chucks, which are made from cast iron and mild steel are of two types, viz. :—

(i.) self-centering;

(ii.) independent;

the former usually having three jaws, and the latter four.

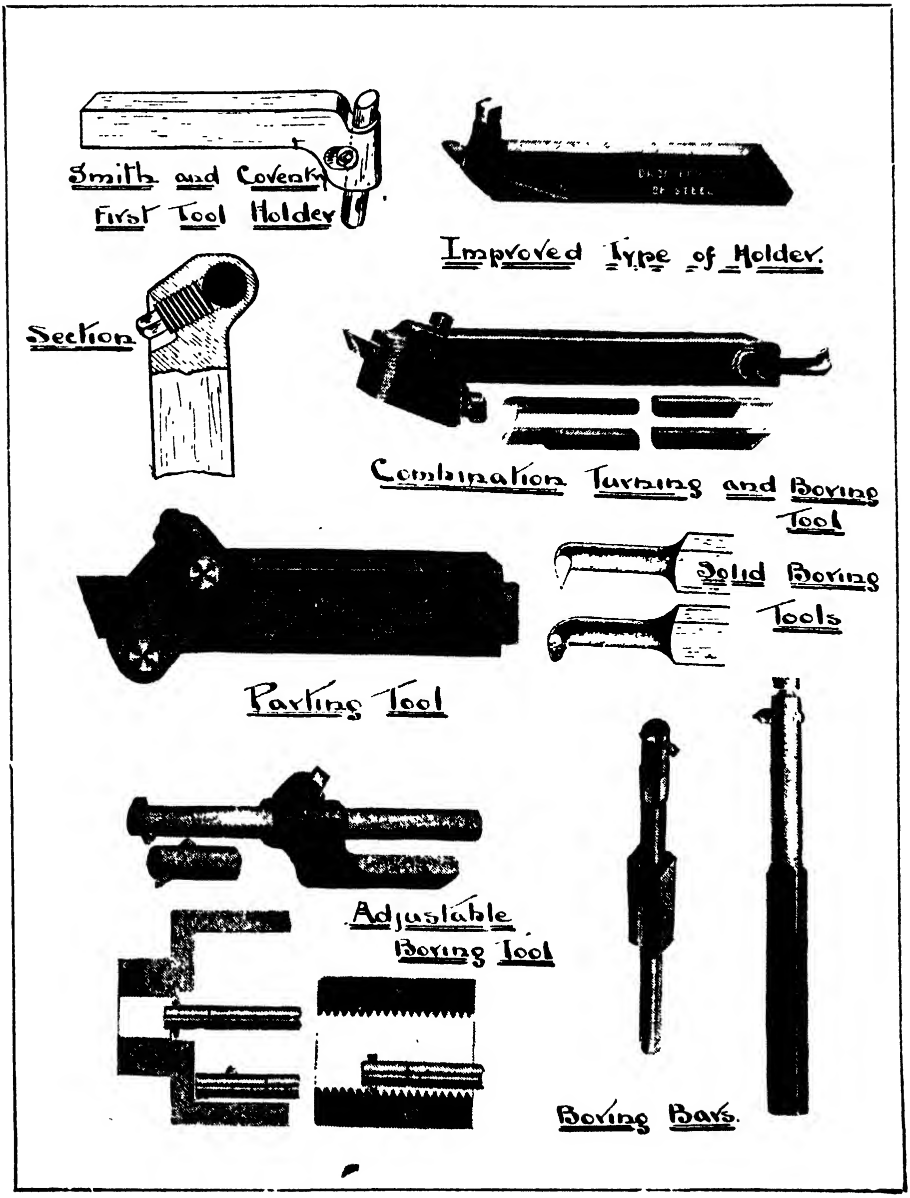


FIG. 71.—TOOL HOLDERS.

(i.) In the SELF-CENTERING or UNIVERSAL CHUCK (Fig. 64), the jaws move together, and always concentric to the lathe mandrel. This movement is effected as follows :—

'*A*' is a bevel pinion wheel with a recess for a key in the end of the spindle. When the key is turned the plate '*B*' is rotated. On the face of the plate '*B*' there is a scroll or spiral having three or four convolutions. The rotation of the spiral moves the jaws nearer to or further from the centre, but equally, each jaw gripping the work at the same instant, equidistant from the centre.

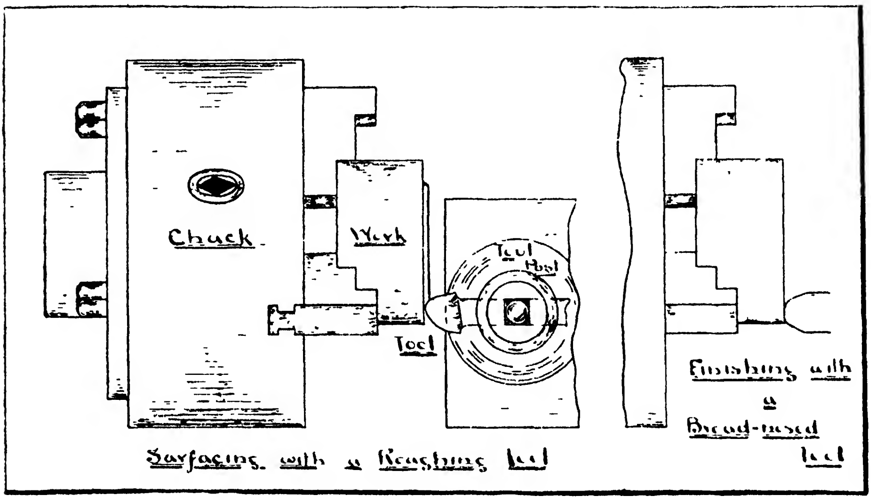


FIG. 72.

(ii.) For work of irregular form the INDEPENDENT CHUCK (Fig. 64) is more serviceable. Each jaw is operated by a screw, but moves separately. By releasing one jaw and screwing up the others, work can be adjusted as required.

To cross traverse the sides, and turn the periphery of discs of any thickness, from say $\frac{3}{8}''$ in thickness, the procedure is always the same, viz. :—

(*a*) Mount work in chuck with the front face as vertical as it is possible to fix it.

(*b*) With a round nosed tool, but with the side rake sloping downwards from right to left, take a rough cut (Fig. 72), which in the case of a casting should cut well below the "skin."

(*c*) If the face has to be recessed, make the sinking now, using suitable tools.

(*d*) With a broader nosed tool make the finishing cut (Fig. 72). The amount of traverse per revolution of the work should always be less than the width of the cutting edge of the tool.

(*e*) Using a knife tool, turn the periphery of the work to the correct diameter as far as the chuck jaws will allow the tool to travel.

(*f*) The disc can now be turned over, and the same processes repeated for the other face and portion of edge.

The underneath side should always be finished first; when the work is machined to dimensions, any rounded corners, or moulds on the top face can be worked with hand tools.

BORING.

The turning of internal cylindrical surfaces is referred to as boring, and is another example of chuck work.

Castings that have to be bored are frequently cored out, and if this has not been done it is necessary first to drill a hole sufficiently large for the boring tool to enter.

A boring tool of the solid type is shown in Figs. 71 and 73. The cutting end is forged at right angles to the shank, and the top face is ground away to give the correct rake, which should be slightly greater than for external work because of the curvature of the material. Adequate side and bottom clearance must also be provided.

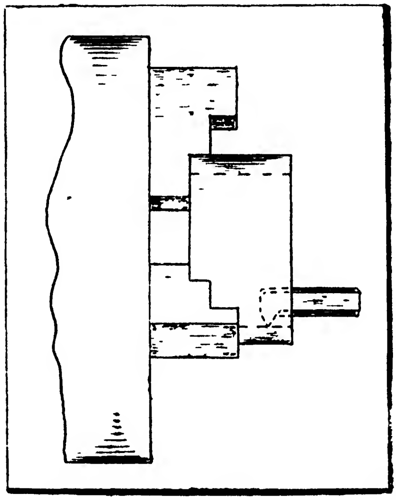


FIG. 73—BORING.

Cutter bars fitted in tool holders are also used. Fig. 71 shows several convenient types.

LUBRICATION.

Much better results are obtained from machine tools if the cutting edges are kept lubricated. Efficient lubrication reduces friction between tool and work, and saves power, besides which, the liquid keeps the temperature of the tool point much below that at which the temper would be withdrawn.

The amount of lubrication possible in the majority of lathes in handicraft rooms is limited however, to allowing the liquid to drop from drip cans just in front of the tool, and it is doubtful if much of it ever reaches the cutting edge, because the shaving, closely pressed down on the top face of the tool, is moving in an opposite direction to that in which it is desired to introduce the fluid. In such circumstances the liquid can only be regarded as a cooling agent, and not really as a lubricant.

LUBRICANTS FOR DIFFERENT METALS.

Mild Steel	Cold water, a mixture of soluble oil and water: or, better still, an emulsion of soft soap and water, with a little soda added to prevent rust.
Copper	Turpentine applied with a brush whilst the tool is traversing the work.
Aluminium	Kerosene and lard oil mixture applied as for copper.
Cast Iron, Brass, Zinc	These metals break up or crumble as they come away from cutting edges and for ordinary cuts need no lubricants.

The graphite in cast iron is also sufficient lubricant for any cut taken in that material, and it should always be turned dry.

For deep cuts in brass and zinc, the emulsion used for mild steel, or frequent oiling of the tool edge is helpful, if only to prevent the cutting point from becoming overheated.

TAPER TURNING.

With the equipment available in the school metalwork room there are three methods of turning tapered work in a lathe, viz. :—

(*a*) By means of a hand tool and rest.

When the amount of taper is not stated, but is merely to give improved shape, as in the case of small handles, brass fittings, etc., this method is as convenient as any, particularly with non-ferrous metals.

(*b*) By setting the work obliquely to the long axis of the lathe centres; the tool travelling parallel to this axis as usual.

The loose headstock (Fig. 61) is jointed at ' *X Y*.' By slackening the holding-down bolt and turning the set-screw, the "dead" centre can be brought forward as in Fig. 75 (*a*).

Suppose a piece of material has to be tapered as in Fig. 75 (*b*), the amount of forward movement given to the top part of the headstock will be equal to half the difference between the diameters ' *D* ' and ' *d*.'

This is straightforward if the work is to be tapered throughout its length, but if the taper is stated on a drawing as so many inches, or a fraction of an inch per foot, and only a portion of the work is to be tapered as in Fig. 75 (*c*), then a calculation must be made to obtain the correct setting of the tailstock, because the adjustment depends not only on the amount of the taper, but on the *total* length of the piece.

RULE.

1. Find the taper per inch.
2. Multiply by the total length of work.
3. One half product is the eccentricity of the centres.

EXAMPLE.

The conical portion ' *C* ' in Fig. 75, has a taper of 1 inch per foot, but the tailstock centre must be brought forward less than one half the taper per foot ($\frac{1}{2}''$), because the total length is only eight inches.

The taper per inch = $^1/_{12}$ inch, and the total length of 8 inches multiplied by $^1/_{12}=\frac{2}{3}''$, half of which = $\frac{1}{3}''$, the amount the tailstock centre should be moved out of alignment with the headstock centre.

The amount of offset may also be found by proportion.

$3''$	:	$\frac{1}{4}''$	: :	$8''$	:	x''
Length of Taper		Difference in Diameter		Total length of piece		Taper if extended throughout the entire length

$$\frac{x}{2} = \text{Offset of centre}$$

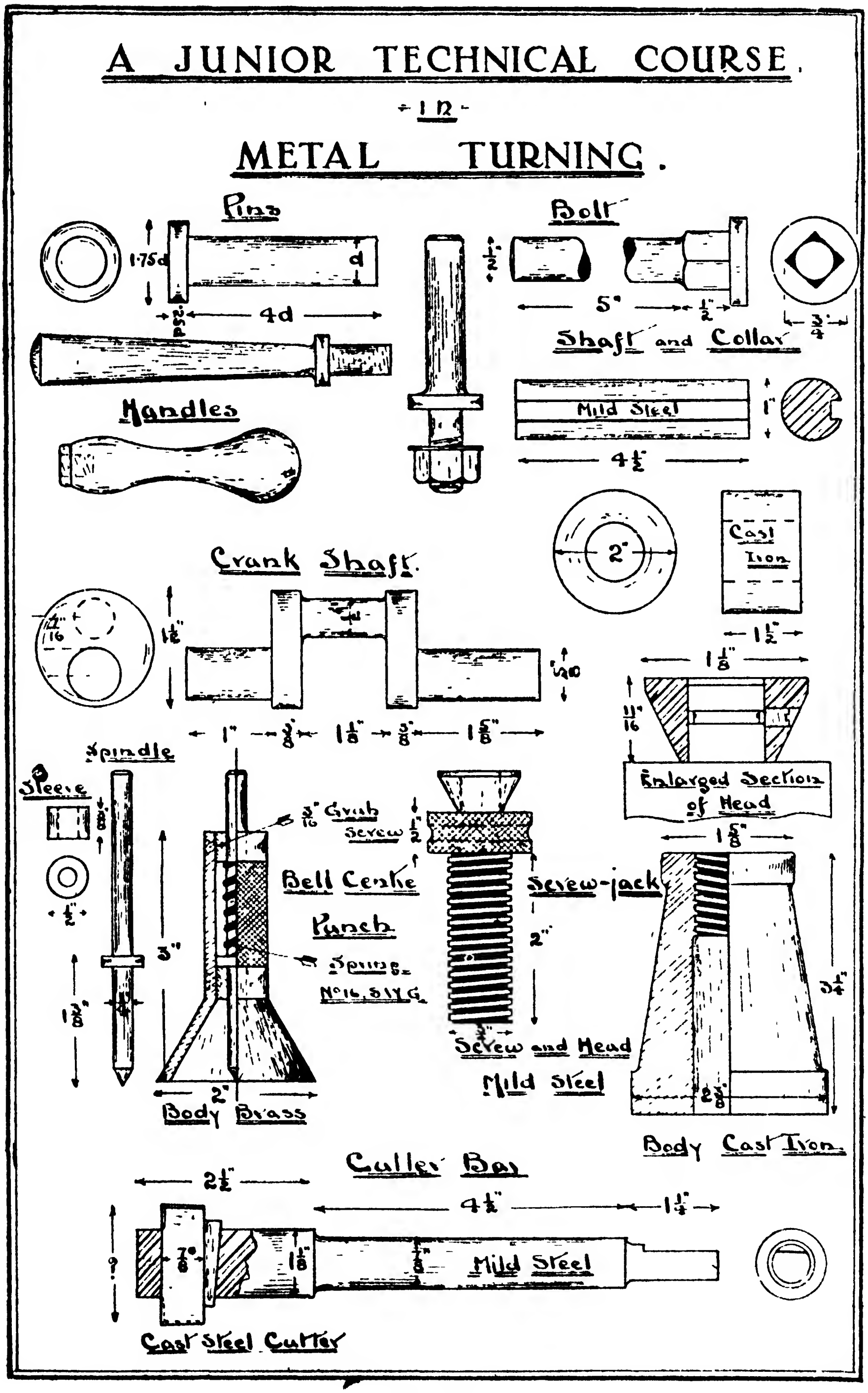

A JUNIOR TECHNICAL COURSE.
IN
METAL TURNING.
Pins
Bolt
Handles
Shaft and Collar
Mild Steel
Cast Iron
Crank Shaft.
Spindle
Sleeve
Bell Centre Punch
Spring
Screw-jack
Screw and Head
Mild Steel
Body Brass
Enlarged Section of Head
Body Cast Iron.
Cutter Bar
Mild Steel
Cast Steel Cutter

FIG. 74.

(c) By causing the tool fixed in the tool post of a compound slide rest to travel obliquely along the work.

The slide rest is fitted with a graduated disc, on which the top slide turns. By setting the top slide (and also the tool fixed to it) at an angle from its normal position, equal to the amount of taper required, the tool travels obliquely to the axis of revolution, and so turns the required taper. The top slide must, of course, be operated by hand.

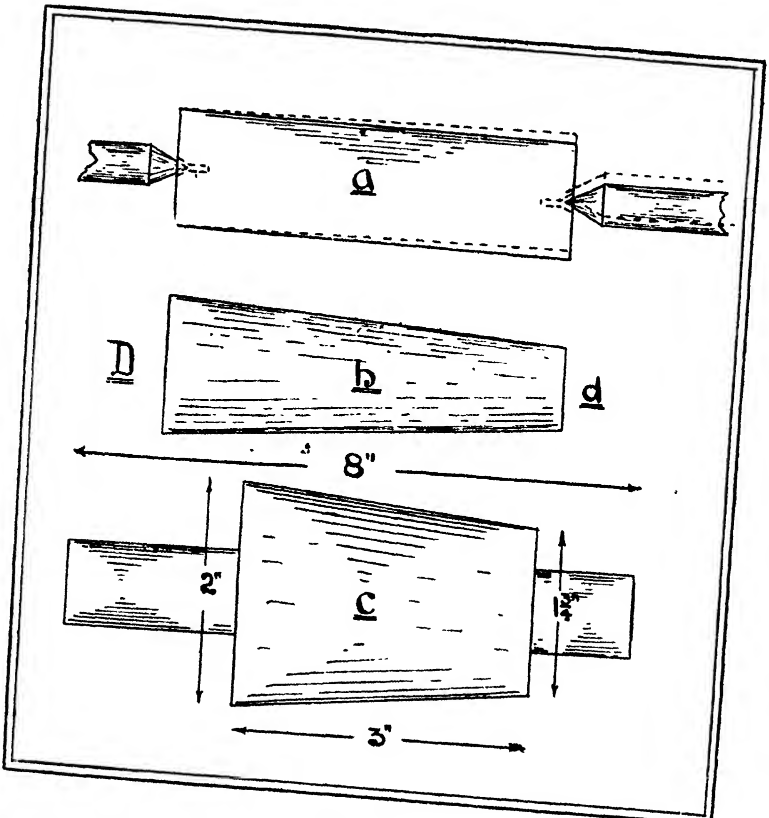


FIG. 75.

The taper required may be expressed as a slope 1 in 10, 1 in 24, etc., and as the disc on the slide rest is graduated in degrees, it is necessary in such a case to convert the slope into its corresponding angle by using a Table of Tangents. This method is convenient for steep or quick tapers, which cannot be turned by method (b) owing to the limited movement of the divided headstock.

CORRECT HEIGHT OF TOOL.

The turning of cylindrical work allows of some variation in the height of the cutting tool edge without the concentric truth of the work being affected, but the turning of conical surfaces requires special care in this respect. The height of the tool must be exactly level with the centre line of the work:— that is, a line described by the point of the tool must, if produced, intersect the axis of the cone, otherwise the surface of the cone will be a hyperboloid of revolution which is curved in the direction of its length or axis (see Fig. 76).

SCREW-CUTTING.

Screw-cutting is a turning process, whereby the tool is forced to follow the same path at every cut whilst the thread is being formed. For accurate work it is essential that gears, and lead screw threads, be kept clean, and the lathe carefully adjusted, so that the tool point travels parallel with the axis of the screw being cut.

Screw-cutting lathes are usually fitted with a number of wheels called "change wheels." These wheels vary in the number of their teeth, from 20, advancing by fives up to 120. There are also two wheels of equal size in the "set," generally two sixties.

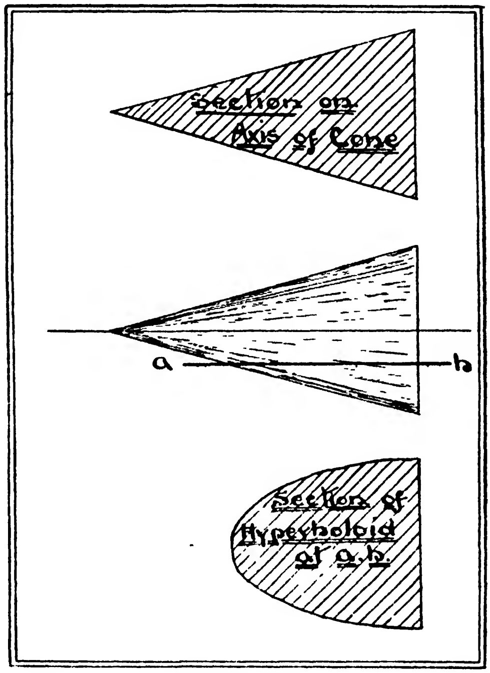


FIG. 76.

The "leading" or "guide" screw of a lathe is the copy from which all other screws are cut, and, on the machines used in handicraft rooms, has four threads per inch

Motion is transmitted from the lathe spindle to the leading screw by means of the change wheels. According to the method of fixing the wheels on the studs, etc., what is called a simple or a compound train of wheels is obtained. A simple train of wheels is one in which all the wheels are in one plane, and a compound train, one in which the wheels are contained in two planes (see Fig. 78).

Fig. 77 shows the arrangement at the left hand end of the lathe for mounting the wheels and causing them to gear with one another. The wheel on the end of the lathe spindle has 20 teeth, and its speed is transmitted by the intermediate wheels each having 20 teeth, to the wheel, also with 20 teeth, on the end of the fixed stud. This last wheel is called the mandrel wheel, and it drives (perhaps through an intermediate wheel), the wheel on the lead screw end.

The ratio of the speed existing between the lathe spindle and the leading screw determines the pitch of the screw to be cut, and the rule for obtaining any required wheels is as follows :—

Rule.—Call the number of threads per inch in the leading screw a *numerator*, and the number of threads per inch it is desired to cut a *denominator*. The fraction expressed gives the ratio of the wheels to be used.

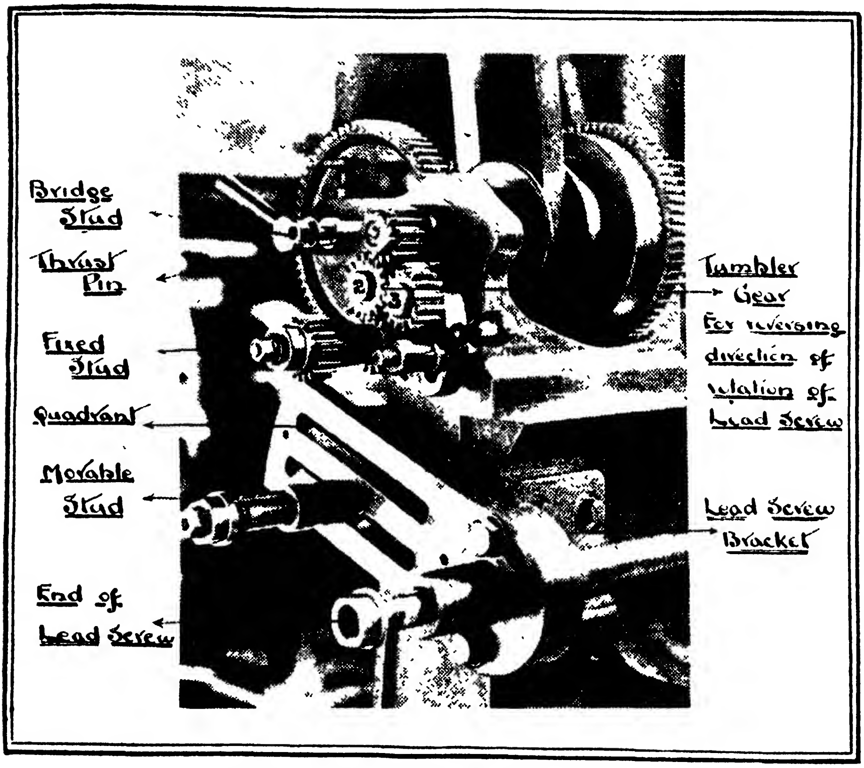


FIG. 77.—SCREW-CUTTING MECHANISM.

Example I.—To cut 10 threads per inch on a lathe having a 4 threads per inch leading screw.

According to above rule $\dfrac{4 \text{ Threads per inch Lead Screw.}}{10 \text{ Threads per inch to be cut.}}$

As there are no wheels with 4 and 10 teeth, we must multiply both numerator and denominator by any number which will suit the numbers of the teeth of the change wheels. Suppose we multiply by 10.

$$\frac{4}{10} \times \frac{10}{10} = \frac{40}{100} = \frac{\text{Driver}}{\text{Driven}}$$

Then a 40 wheel on the lathe spindle and a 100 on the leading screw end, with any intermediate wheel sufficiently large to connect them, constitutes a simple train of wheels for cutting 10 threads per inch. Two points need to be noted :—

1st.—The intermediate or carrier wheel does not affect the velocity ratio existing between a driver and driven wheel: only the direction of rotation of the leading screw is affected.

2nd.—The wheel represented by the numerator of the fraction goes on the lathe or mandrel spindle, and that by the denominator on the leading screw end.

Example II.—To cut a special thread of say $7\frac{1}{2}$ threads per inch.

$$\frac{4 \text{ No. of threads in lead screw.}}{7\frac{1}{2} \text{ No. of threads to be cut.}}$$

Simplify the fraction; thus $\frac{8}{15}$

Multiply by 5 to make numerator and denominator agree with wheels in the "set."

$$= \frac{8}{15} \times 5 = \frac{40}{75} = \frac{\text{Driver}}{\text{Driven}}.$$

Example III.—Train of wheels required to cut $6\frac{1}{4}$ threads per inch.

$$\frac{4}{6\frac{1}{4}} = \frac{16}{25}$$

If multiplied by 5, the lowest number possible, the result is 80/125, but there is no 125 wheel in the set, and it becomes necessary to compound the wheels by factorising:—

$$\frac{16}{25} = \frac{4 \times 4}{5 \times 5} = \frac{40 \times 40}{50 \times 50}$$

As there are not two 40s and two 50s, change one of each by multiplying them by 2. The train then becomes:—

$$\frac{40}{50} \times \frac{80}{100} \frac{\text{Drivers}}{\text{Driven}}$$

This compound train of wheels is similar to that illustrated in Fig. 78.

To prove whether train is correct.

$$\frac{\text{Drivers multiplied by No. of threads per in.}}{\text{Driven " " " " in lead screw}} \quad \frac{= 40 \times 80 \times 6\frac{1}{4}}{= 50 \times 100 \times 4} = 1$$

On cancelling, the two quantities are found to be equal and therefore correct.

Fractional Pitch.—The pitch of the required screw may be expressed in the form of a fraction instead of so many threads per inch. In such a case the wheels are obtained as follows:—

Rule.—Multiply the required pitch (say $\frac{1}{8}''$) by the number of threads per inch in the leading screw.

Example I.— $\dfrac{1}{8} \times \dfrac{4}{1} = \dfrac{40}{80} \quad \dfrac{\text{Driver}}{\text{Driven}}$

Example II.—To cut a screwthread of $\frac{3}{8}''$ pitch.

$$\frac{3}{8} \times \frac{4}{1} = \frac{12}{8}$$

Multiply by 5 to obtain wheels in " set "

$$= \frac{60}{40} \quad \frac{\text{Driver}}{\text{Driven}}$$

This example shows that 8 threads of $\frac{3}{8}''$ pitch are contained in the same length as 12 threads $\frac{1}{4}''$ pitch of the leading screw.

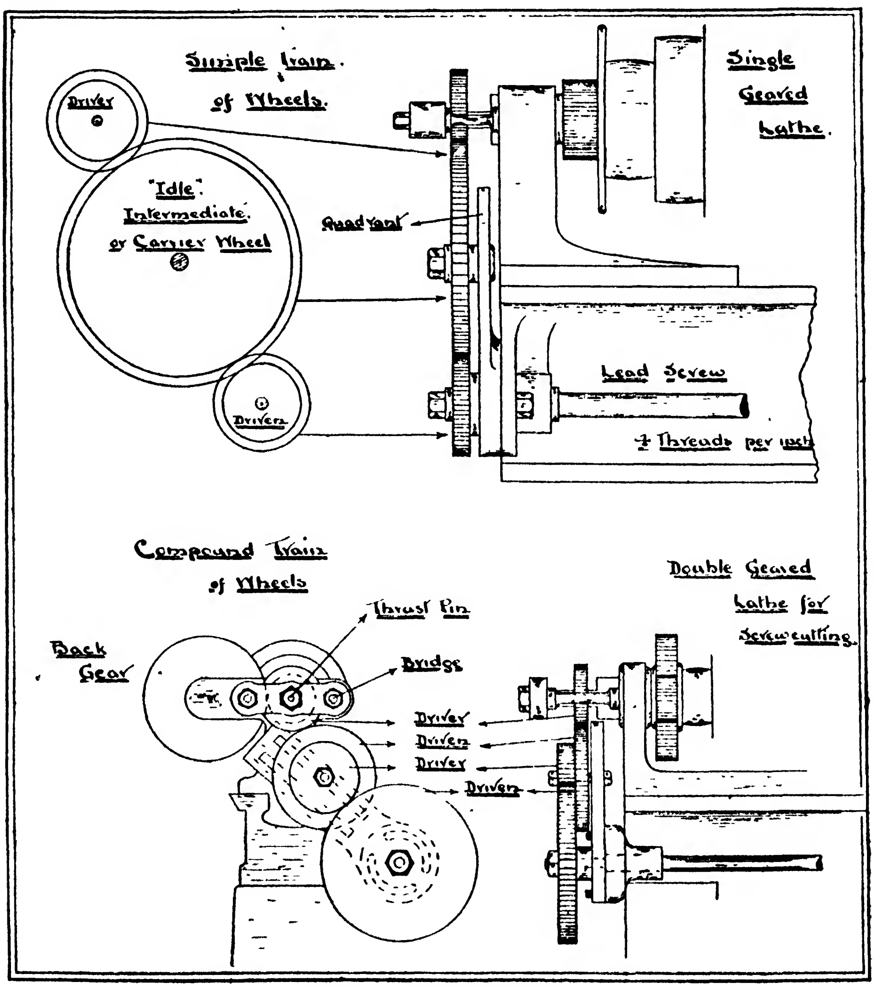


FIG. 78.—TRAINS OF WHEELS.

RETURN OF SLIDE REST AFTER EACH CUT.

When a cut has been made with a screwcutting tool, the carriage or saddle is returned to the original starting position by hand, preparatory to putting on more feed and taking another cut, and in order that the nut shall gear in the correct place for the tool, it is necessary that the distance passed over shall contain a complete number of the threads that are being cut, and also a complete number of threads of the leading screw :—Thus in the case of a screw of $\frac{5}{8}''$ pitch, the least distance the saddle can be moved so that the tool will fall into its proper place is $1\frac{1}{4}$ inches. In this distance there are two threads being cut, and also five of the leading screw threads. Any multiple of $1\frac{1}{4}''$ can be used as required by the length of the screw being cut.

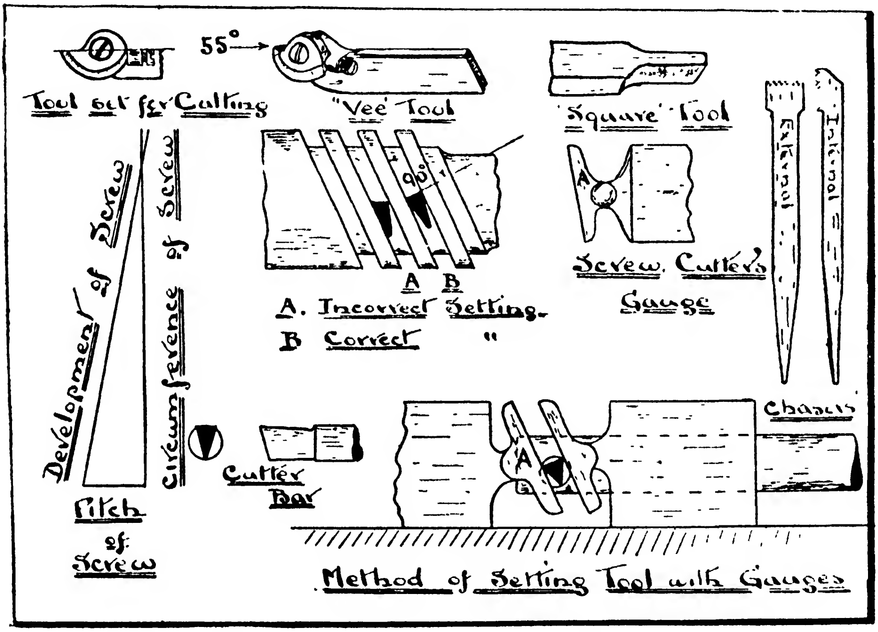


FIG. 79.

SCREWCUTTING TOOLS.

Fig. 79 shows two screwcutting tools—one with a cutting disc ground to an angle of 55° for Whitworth vee threads, and which only requires sharpening on the top face, and the other ground to fit a notch in a screwcutting gauge (see Fig. 64), according to the width of groove required; in the case of a single square thread this being P/2 see Fig. 17.

CORRECT SETTING OF TOOL.

When fixing a tool in the lathe for cutting a thread, care must be taken to see that it is so placed as to have its cutting edge at right angles to the direction of the helix or screw; for if this is not done the width of the groove between two threads will be less than the width of the tool. In Fig. 79 the section of the cutting tool '*A*' shows the tool wrongly placed. The position at '*B*' is correct.

For general work, before commencing a cut, the tool should be clamped as nearly as can be estimated in the correct position, then, after taking one or two cuts over the work, so as to see the screw clearly and distinctly, the angle between the side of the thread and the cutting edge may be examined, and, if not correct, the tool slackened and properly adjusted before proceeding further with the cutting.

This method cannot be applied in the case of an internal thread, and the "setting" of the tool must be done accurately before commencing the cut. If the tool is a solid one, that is, not a small cutter bar inserted in a holder, but one forged to shape and afterwards filed and ground, such grinding must be very carefully done to the proper inclination or "rake" to suit the pitch of the thread. An example will make this clearer. Suppose it is required to cut an internal square thread $\frac{3}{8}''$ pitch, $1\frac{1}{2}''$ diameter. The inclination of the thread is obtained by drawing two lines at right angles, and along one, set off the circumference at the top of the thread, *e.g.*, $1\frac{1}{2} \times 3.1416$; and along the other the pitch $\frac{3}{8}''$. The line joining the points is the development of the screw, or, as turners term it :—"the rake of the screw" (see Fig. 79).

A tool so set that the inclination of its centre line corresponds to the inclination of the thread, will be in the proper position for doing its required work.

The method of setting a small cutter bar in a tool holder, with a pair of screwcutter's gauges, is shown in Fig. 79. The gauges are readily made, and afford a good vise work exercise. The swivelling piece '*A*' is rivetted to the parallel piece of plate, and has a movement similar to that of a caliper head.

LEFT HAND THREAD.

To cut a left hand thread, the direction of rotation of the leading screw must be reversed, and this is brought about by the arrangement of small wheels, called a "tumbler gear," illustrated in Fig. 77. The wheels 2 and 3 are attached to a rocking arm fitted with a handle. When the arm is down, and wheel 2 in gear with the train, as shown in the illustration, the leading screw will revolve *with* the lathe mandrel, and the tool will cut a right hand thread. When the arm is moved to the up position, and wheel 3 brought into gear, the leading screw and mandrel revolve in opposite directions. The slide rest now travels from left to right, causing the tool to cut a left hand thread.

THREADS OF METRIC PITCH.

It is usual to state the pitch of a metric thread in millimetres, instead of the number of threads per inch.

When using an English screw-cutting lathe to cut such a thread, it is necessary, first of all, to determine the number of threads per inch corresponding to the pitch in millimetres. There are 25.4 millimetres in an inch, and if the required pitch is say 3 millimetres, the number of threads per inch will be $25.4 \div 3$.

Rule.—Place the number of threads in the lead screw (say 4) as numerator, and the number of threads to be cut as denominator.

$$\frac{4}{\dfrac{25.4}{3}} = \frac{4 \times 3}{25.4}$$

Now multiply by a convenient number to determine the correct wheels. The only convenient number by which 25.4 can be multiplied so as to obtain a whole number is 5.

$$25.4 \times 5 = 127.$$

A wheel having 127 teeth must always be used when cutting metric threads in English lathes.

The other wheel required in this case is one with 60 teeth.

$$\frac{4 \times 3 \times 5}{25.4 \times 5} = \frac{60}{127}$$

Rule for all cases.—Threads in lead screw $\times$ pitch of required thread $\times$ 5 = numerator.

127 = denominator.

The wheel obtained by the numerator quantities goes on the mandrel end or stud, and the 127 wheel on the leading screw.

CHASING A THREAD.

Vee threads after being cut in a screwcutting lathe may be finished to size and shape with chasers. The work is run at a higher speed, and the tool operated in a similar manner as a hand turning tool (see Fig. 21*b*).

Fig. 79 shows chasers for external and internal screw threads.

BOOKS FOR REFERENCE.

"Cutting Tools"—R. H. Smith.

"Engineering Workshop Practice"—C. C. Allen.

"Turning and Boring"—"Machinery" Publications.

"An introduction to Metal-working"—J. C. Pearson.

CHAPTER XIII.

Moulding and Casting.

CASTING is the reducing of metal to a fluid state by means of heat, and then pouring it into moulds, the cavities in which have been formed by " patterns."

The processes can be readily carried out in the handicraft room with very little equipment, and the scheme, if regarded from the point of view of practical metallurgy, possesses considerable educational value. With school-made apparatus and few tools, facilities may be provided in the metalwork room for demonstrating, in an experimental way, the properties of metals and their use in foundry practice, with the added advantage that, whilst supplementing the work of the school laboratory, the experiment may be carried further, and the " casting " made to serve some useful purpose.

The impossibility of obtaining temperatures sufficiently high to fuse cast iron and brass in order to make them flow, limits the scope of the work to some extent, but lead, type metal, and aluminium can all be readily melted on the hearths described in " Forge Work," and used, not only for projects for which they are particularly suitable, but to demonstrate generally the principles of metal casting.

When brass and cast iron must be used, an arrangement with a local foundry might be made, to permit of students being present when castings are being taken from patterns they have made.

EQUIPMENT.

Fig. 81 illustrates a moulding equipment which has served well for a number of years. The apparatus is self contained. The bench or " moulding tub " has a removable flat top, and can be used as a drawing or marking out table when not otherwise required, whilst the cupboard underneath the " tub " accommodates all the necessary small tools and appliances.

APPARATUS NEEDED.

Two pairs of " flasks " 14″ × 10″ × 8″ (see Figs. 81 and 83).
One riddle 20″ diameter, ¼″ mesh.
One sprinkler made from fine gauze stretched on a wooden frame.
One pair of small hand bellows.
Three or four rammers, 2″ × 1″ and 2″ diameter.
One trowel.
A few moulder's tools.
A " gate " cutter made from tin plate.
One or two " sprue pins " for " gates."
A few moulding boards battened on one side.
Vent wires, *e.g.*, knitting needles, umbrella ribs, etc.
Moulding sand, 1 cwt.
Brick dust, 14 lbs.
Parting sand, 14 lbs.
Pea Meal, ½ lb.
Linseed Oil (boiled) for core making.

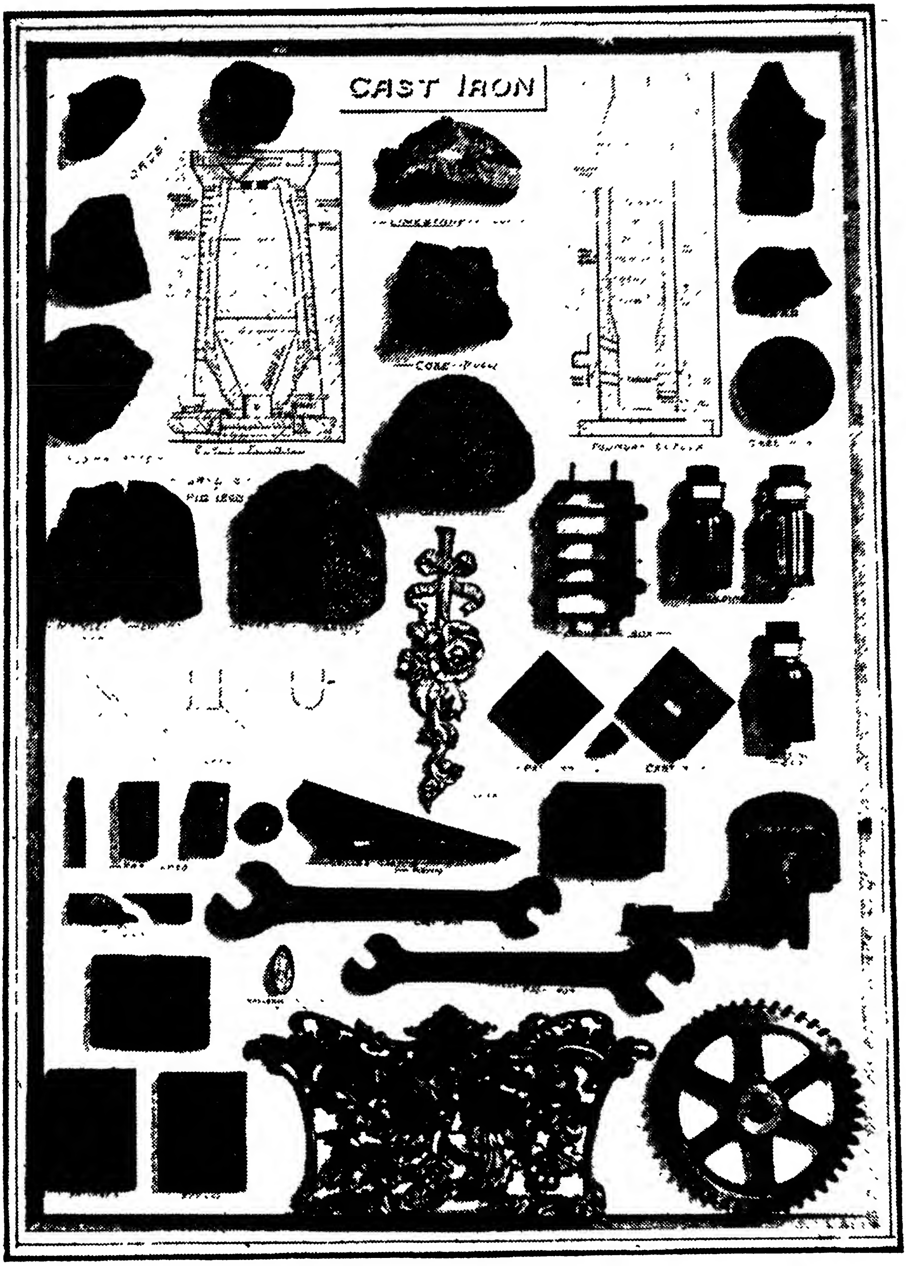


FIG. 80.

ILLUSTRATIVE MATTER FOR LESSONS ON MOULDING AND CASTING.

SOUND CASTINGS.

For the production of good castings, three things are necessary, viz. :—

I. A well made pattern of selected material and good design.

II. Purity of the "founding" metal.

III. The skilled craftsmanship of the moulder.

THE PATTERN.

Dependent on the way in which they may be withdrawn from the mould, patterns may be made in one piece (see Fig. 82), or they may be divided and the parts held together by dowelled joints (Fig. 84). They may also be solid, as in the case of the pattern for the "blast nozzle," (Fig. 83), but the casting taken from it hollow. Such a casting is termed a "cored casting," and in addition to a pattern being prepared for it, a core box (Figs. 82 and 83) must be made in which to mould a sand core, the core being afterwards baked in an oven.

The purpose of the core is to leave a hole or recess of a particular shape in the casting which it would be impossible to make by the use of the pattern alone.

When making a pattern, it is necessary to consider machining allowance and contraction. Castings that only require dressing off and roughly finishing, *e.g.*, dry nozzles for smithy fires, vise clamps, etc., can be made to the sizes specified on drawings, but others, *e.g.*, screw-jack bodies, bases and uprights for stands, etc., which are to be machined and finished in lathes, must be given an allowance of metal varying from $\frac{1}{8}''$ to $\frac{1}{4}''$, in order that they may finish to size.

Allowance must also be made for the contraction of the metal when cooling. The shrinkage of cast iron is about $\frac{1}{8}''$ per foot; that of brass slightly more. This shrinkage may be allowed for by using a contraction, or pattern makers' rule, which is calibrated like an ordinary steel rule, but made longer by the amount per foot the various casting metals contract. To facilitate the easy withdrawal of the pattern from the mould, without the sand being lifted or broken, a slight taper is given to the "square" parts. This is called the "draught" or "draw" of the pattern, and on external surfaces is $\frac{1}{4}''$ per foot, but for internal holes is often increased to $\frac{3}{4}''$ per foot.

The side of the pattern to be first removed from the mould is the "face side," and when commencing moulding this side is always placed downwards on the moulding board (see Fig. 84).

Yellow pine and bay wood make the best patterns, but any timber not highly resinous, easy to work, and not liable to warp when subjected to alternate dry and moist conditions may be used. Kauri pine has been found to give good all round service in the course illustrated in Fig. 82.

Finished patterns should be given a couple of coats of thin spirit varnish to produce a hard, smooth surface, and the inside of core boxes should be treated in the same way.

In pattern making shops, it is usual to varnish the core prints on patterns black, and the inside of the core box, which accompanies the pattern, is also blacked with a mixture of lamp black and shellac in methylated spirit.

METAL.

A good casting metal for demonstration purposes may be made from 70 parts lead, 25 parts zinc, and 5 parts antimony. The latter is added because of its peculiar property of expanding as it solidifies, thereby producing a

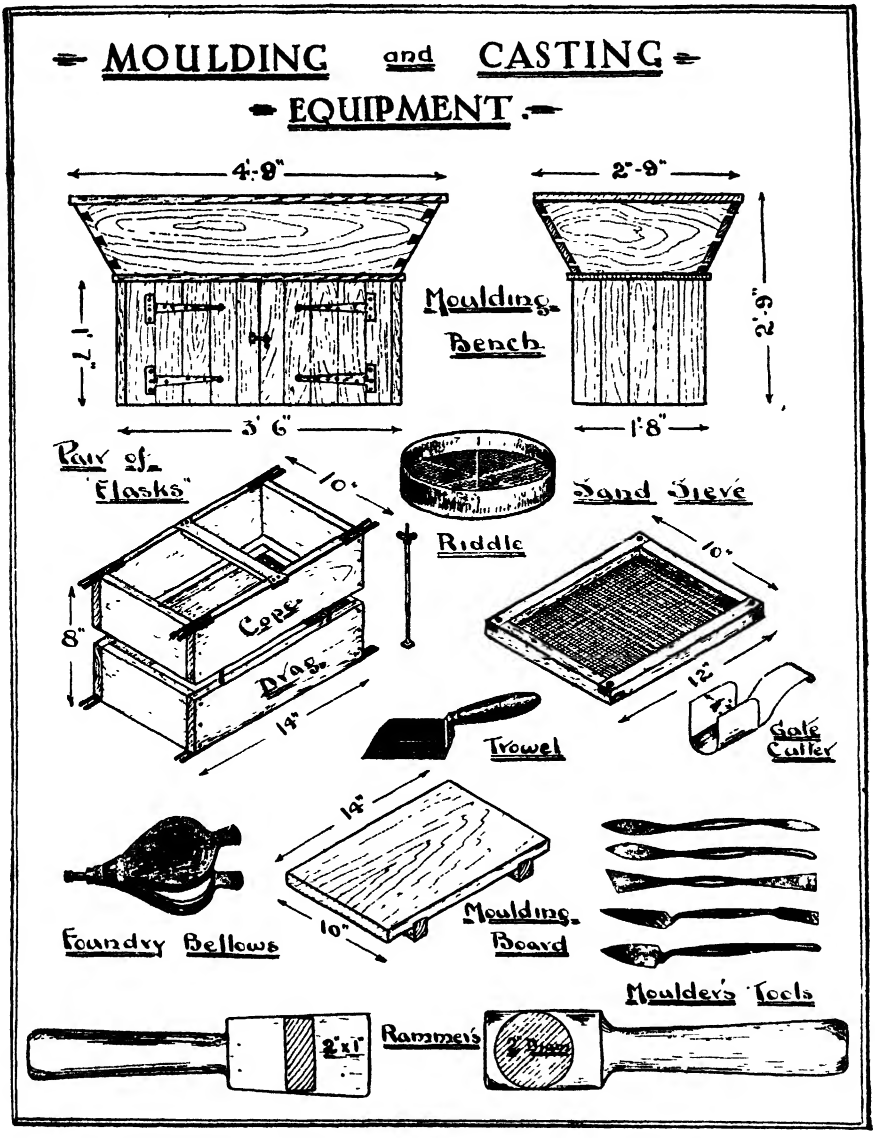


FIG. 81.

casting of sharp outline. The preparation of this "compote," forms a good example of alloying metals, and because of the valuable lesson afforded, is to be preferred to the use of scrap lead or type metal.

All these metals fuse at low temperatures, and can readily be melted in a plumber's ladle on the forge fire.

A word of caution is necessary. Molten metal has a tendency to " fly " when allowed to come in contact with damp, and when pouring, the operator should not stand over the mould, but well to the side of it.

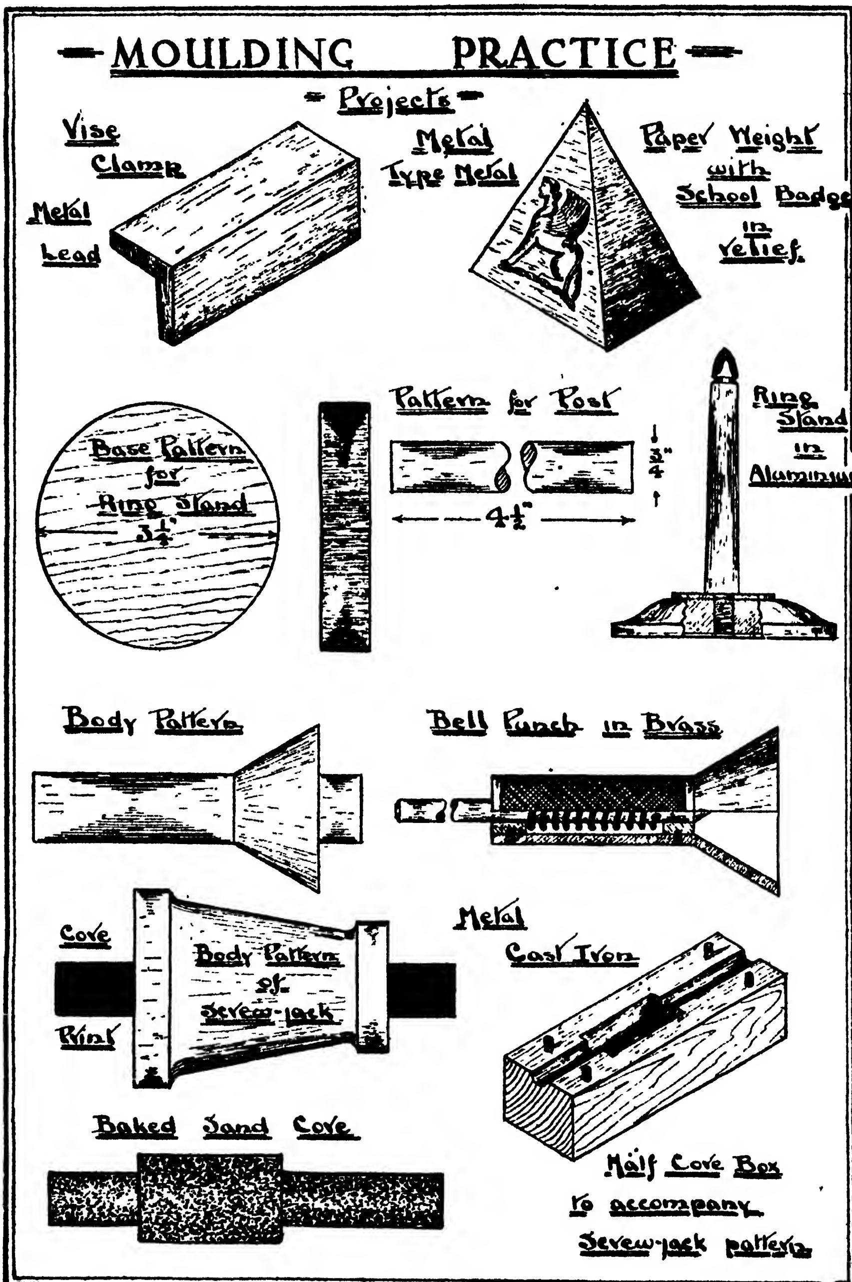


Fig. 82.

MOULDING.

The simplest form of moulding consists in making up a bed of sand, pressing a pattern into it, withdrawing the pattern which leaves an imprint in the sand, and running metal into the cavity made. The metal on solidifying retains the shape of the pattern, and in order to prevent the sand from being displaced by the weight of metal it is necessary to confine it in a box or boxes called " flasks," (see Fig. 83).

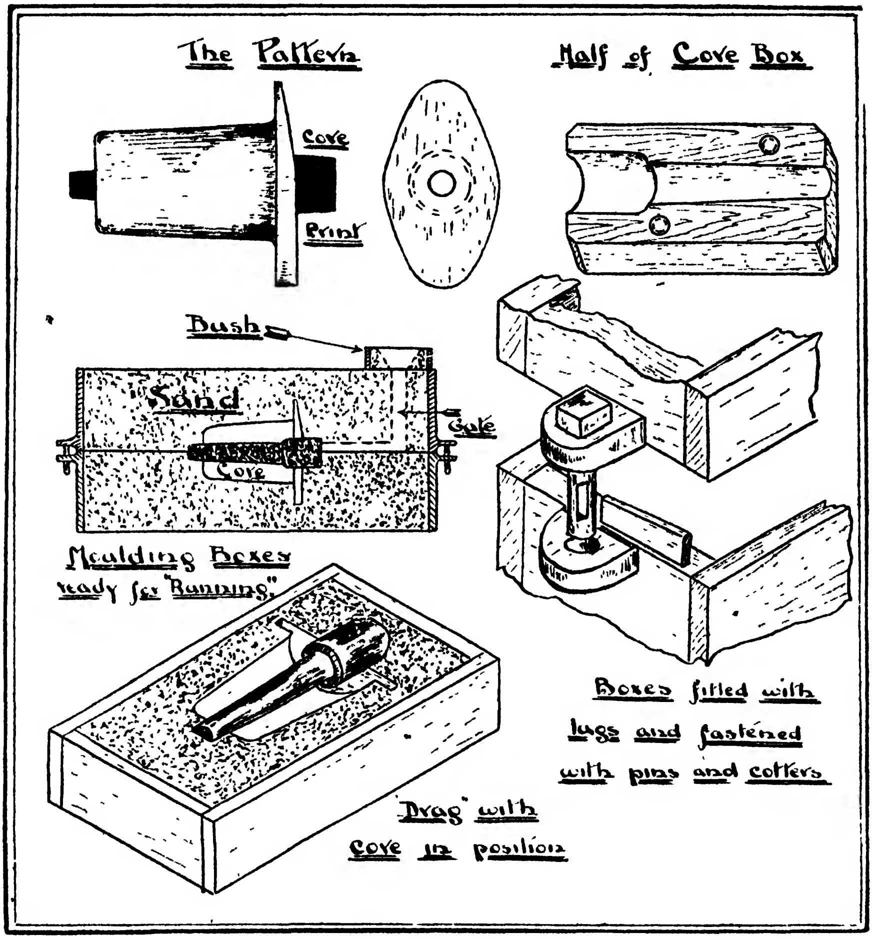


FIG. 83.—AN EXAMPLE OF FLASK MOULDING A DRY NOZZLE IN CAST IRON.

The flasks used in the metal workroom are stoutly made boxes, dovetailed at the corners, and left without bottoms. A convenient size is 14" × 10" × 4", and each pair should fit exactly one on the other. The bottom box is known as the " drag," and the top one as the " cope."

Various methods are adopted for clamping the boxes together so as to be in perfect register, and at the same time preventing any tendency for the " cope " to lift, when gases are generated by the hot metal in the mould.

Fig. 81 shows a pair of flasks dowelled together and held in position by bolts fitted with wing nuts, whilst Fig. 83 shows a section through two moulding boxes fitted with lugs. The lugs on the cope are provided with slotted pins, and those on the drag are bored to receive the pins. Cotters through the slots clamp the boxes together.

SAND.

The sand used in flask moulding is known as Green Sand, because the best of its kind is obtained from the Green Sand Measures. That obtained from the local foundry will be black, due to constant usage, and the frequent admixture of graphite when large moulds have been built up in the foundry floor. The sand contains a large percentage of silica to give porosity, and alumina for binding purposes. Parting sand is fine sharp sand, used dry to form a thin layer between the two flasks, and prevent the damp sand in the two boxes from adhering. Brick dust may be used for the same purpose, and for sprinkling through a fine sieve (see Fig. 81), over the pattern before the damp sand is rammed round it. Core sand is a mixture of coarse sand, rock sand, and loam. When being prepared for use, it is made sufficiently damp with linseed oil, to make it bind together after it has been moulded in the core box.

TEMPERING THE SAND.

The moulding " tub " illustrated in Fig. 81 will conveniently accommodate one hundredweight of sand, and to get this ready for use, it must be turned over and worked with the trowel, whilst being wetted with water from a sprinkling can. The process should be continued until the sand is just damp enough to pack when gripped in the palm of the hand. On no account should it be wet or sloppy, and when once in good working condition should be kept so by an occasional sprinkling.

MOULDING PROCESSES.

In order that students may obtain a sound knowledge of the principles of moulding practice, it is advisable to allow them to work in pairs, and cast three moulds from single, halved, and cored patterns respectively.

The construction of a one-piece pattern will determine which side should be withdrawn from the sand first. As before stated, this side is the " face side," and lies flat on the moulding board, whilst the " drag," bottom side upward, is being rammed with sand (See Fig. 84, I.).

The moulding of a pattern in two halves—A flanged pipe with a cored hole through the middle is illustrated in Fig. 84. The halves of the pattern are dowelled together (the joint being an easy, but not a slack fit), and because of this it is necessary when commencing work to place the piece without the dowel pin on the moulding board.

The processes of carrying the job through are as follows :—

1. Place the half pattern in position on the moulding board, and sprinkle with brick dust through a fine sieve. (Fig. 84, I.).
2. Put the drag in position, ' I.' Provision for running the metal must be considered when this is being done.

3. Ram with sand which has been screened through the riddle (see II.). The flask must be completely filled, otherwise the sand will be pushed down when the cope is being rammed, 'III.'
4. Turn the drag over on to a clean moulding board; place the cope in position and secure with bolts, etc. Arrange the " gate " or " sprue

Fig. 84.

pin " so that the runner from it will distribute the metal conveniently into the mould, and sprinkle with brick dust or parting sand. Fill the flask and ram firmly (III.).

NOTE.—The gate is never placed directly over the mould The weight of falling metal would break the sides, with serious results. Provision must be made for the escape of gases generated in the mould, otherwise " blow-holes " and other defects are bound to appear in the casting. When the volume of gas is likely to be considerable, " risers " passing through the sand in the top box are the best means of escape ; the " risers " being formed

FIG. 85.

by pushing a piece of thin wire, or umbrella rib, through the sand until it touches the pattern and then withdrawing. (See also Note after VI.).

5. Open the flasks and expose the pattern, half of which is in each box. Cut the runner from the foot of the gate with the gatecutter, and make the sand quite firm in the groove. Gently loosen the pattern and withdraw with a "draw-spike." Fig. 85, IV.

6. Touch up the edges of the mould with moulder's tools, place the core with its ends resting in the two prints, 'V.'; blow out any loose sand with the bellows.

NOTE.—To obtain smooth surfaces on castings, it is common practice to dust the moulds at this stage with pea meal or powdered graphite. When heated by the molten metal these give off carbon dioxide gas, which fills the interstices between the sand particles, and prevents the metal running in.

Vents, or horizontal grooves in the sand may be provided as an alternative method to that of "risers." The grooves are formed by laying stout pieces of string on the sand at intervals round the flask. When the two boxes are placed together, and the string dragged out a small channel is formed in the sand which allows the gases to escape from the interior of the mould to the outside.

FIG. 86.—A GROUP OF CASTINGS

7. Fix the boxes together finally, see that all fastenings are secure. Melt sufficient metal in a ladle to fill the mould and gate hole, and, after skimming off the dross, pour the mould (VI.).

NOTE.—It is important to fill the gate hole with molten metal, as the head of pressure of the fluid forces the metal well into the corners of the mould, and gives sharp outlines to the edges of the casting.

That this pressure is considerable is seen by a comparison of the specific gravities of fluid lead and the standard liquid, water, viz., 11.4 and 1.

A column of water 2.3 feet in height and 1 square inch in section exerts a pressure at its base of 1 lb., and as the relative weight of lead is almost 12 times as great, the column need only be about 2¼ inches high for the same pressure to be maintained.

Liquids transmit pressure equally in all directions, consequently, the pressure on all surfaces of a mould fed from a gate 1 square inch in section and 6 inches high is approximately 3 lbs. per square inch. The head of pressure may be increased by placing a " bush " over the gate as shown in Fig. 83.

It is interesting to watch the metal in the gate hole during cooling, as it affords a good example of the " piping " that takes place at the point of solidification of all metals, and is such a source of trouble to all metal founders.

When the metal is cold and the mould broken, the casting will have attached to it the body of metal that formed in the gate hole. This has to be cut off with a hack saw, before scrubbing the project with a wire brush to clean away embedded sand, and finishing with files. A group of roughly finished castings is illustrated in Fig. 86.

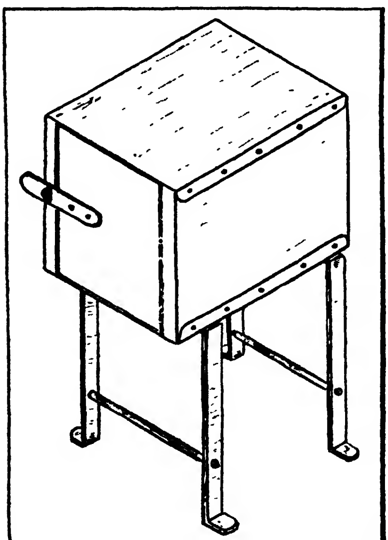


FIG. 87.—OVEN TO STAND OVER A SOLDERING STOVE.

PREPARATION OF CORES.

The sand and earths used for baked cores must be chosen from materials that will bind together, and yet be of such a composition that the bond may be easily broken, and the sand shaken from the finished casting.

Raw linseed oil and sieved rock sand well worked together, and made a little damper than moulding sand, form a very satisfactory core making mixture. The sand is packed into the core box, and the moulded shape then carefully turned out on to an iron plate for transference to the oven.

The baking of cores may present some difficulty in the handicraft room, as it is important that they should be heated as uniformly as possible, and some type of oven is necessary.

The muffle furnace shown in VII. has given very good results, but a small oven, Fig. 87, can readily be made from No. 18 sheet iron, and arranged to stand over a soldering stove.

After baking, the core is improved by giving it a coating of blacklead, which seals the pores of the sand, and prevents the metal from keying to it.

It is scarcely necessary to add that care and cleanliness must be strictly observed during the performance of this branch of metalwork.

All apparatus, tools, etc., should be thoroughly cleaned after using, and stored away in places allotted for them in the body of the moulding bench.

BOOKS FOR REFERENCE.

Mechanical Engineering, Lineham. Chapman and Hall.

Wood Pattern Making, Hanley. Bruce Publishing Co.

General Foundry Practice, McWilliam and Longmuir. Griffin and Co.

Iron Founding Practice, Cassell's Workshop Series. Cassell & Co.

CHAPTER XIV.

The Decorative Treatment of Metals.

THE metal-working occupations to be described in this chapter may be classed as secondary; not in the matter of importance, but because the successful pursuit of them depends, in a large measure, upon a knowledge of fundamentals, or primary operations already dealt with.

In the Aim of Scheme, Chapter I., the need of students possessing artistic ability is recognised, and scope must be provided for the incorporation of aesthetic design, as distinct from technical, into constructive problems.

By a combination of the two ideas—aesthetic and constructive, a thought element is added and brought into close relationship with motor activity, and a new value is thus given to school metalwork.

The main criticism urged against our handicraft methods is, that too much prominence is given to muscular and mechanical dexterity, and too little attention paid to thought development: the projects made being regarded and valued as proofs of skill, than as signs of mental growth.

On the other hand, many enthusiastic teachers who claim that the worth of the subject rests only on its thought basis, have so ignored traditional and controlling ideas in the crafts, that conceptual thinking on the part of pupils has been unable to find adequate expression because of the lack of manual skill, acquired only through tool practice and disciplinary exercises.

The problem of applying Art to Metalwork, and constructing a workable scheme, is one of the most interesting the handicraft teacher is called upon to solve, and in class, the supervision of design, adjustment of practical work to individual ability, and the frequent demonstration of many and varied processes, bring into play all the phases of skilful teaching.

A Scheme that has been found to be a rational one classifies the work into three grades:—disciplinary, transitional, and individual, thus:—

DISCIPLINARY.

All boys to pierce a simple piece of work:—an escutcheon plate, hinge, stencil, etc., see Vise work.

Each student to work a simple repousse design in low relief.

Each student to complete three or four forge work exercises, see Forge work.

Each student to have some experience in hard and soft soldering, see Sheetmetal work.

Each student to raise a small project in copper:—ash or desk trays, sconce reflector, etc.

The design of all these projects to be discussed with the class or group. Suggestions arising out of the discussion may be selected, but every encouragement should be given to independent thinking, and to thoughtfully planned original work which a gifted student may produce.

TRANSITIONAL.

Each student to select and execute a piece of work from one or more of the following craft-groups.

NOTE.—If a new or more difficult process is introduced, an exercise to be worked, or a piece of metal experimented with, before the actual project is commenced. For example, before attempting the twists on the uprights of the fire screen in Fig. 101, a student would be well advised to make a similar twist on a spare piece of iron of the same section, in order to become familiar with the technical details involved in the process.

Group I.—Pierced work. Hanging lamps, lamp shades, spoons, trivet and footman tops, table stands, etc.

Group II.—Repoussé. Name and finger plates, trays, plaques, frames, panels, bowls.

Group III.—Etching, Handles, frame borders and panels, box tops, book ends.

Group IV.—Inlaying. Borders, panels, boxes, small trays.

Group V.—Metal Plate work. Boxes, caskets, geometrical bowls, syphon and jar holders, chestnut roasters.

Group VI.—Wrought Iron work. Handles, hinges, andirons, lamps, screens, grills, brackets.

Group VII.—Hollowing and Raising. Trays, dishes, bowls, chalices.

AIDS.

Specimens of work in each group, drawings, diagrams, etc., should be available for students to examine, and to be used for developing and strengthening habits of observation.

A few good books including such subjects as Principles of Design, Industrial Design, History of the Crafts, etc., should also be included in the handicraft library, and students encouraged to use them, and base their own designs on suitable and well chosen examples. The personal expression of the individual is the end in view, but this can only be attained through the study and adaptation of historical forms, and the inspiration to be derived from the work of the past.

INDIVIDUAL WORK.

The design and execution of a piece of metalcraft, the choice of which is entirely the student's own. The original conception may require modification on the advice of the teacher before aesthetic decisions are finally made, and ideas of construction discussed and clarified before the work is commenced.

In schools where there is close co-operation between Art and Handicraft we have the most favourable environment for the development of aesthetic impulse and constructive ability. Where such a happy relationship exists the work may be apportioned as follows :—

ART.	HANDICRAFT.
Lettering. Appreciation of form. Principles of ornament. Elements of design. Treatment of decorated areas and borders. Colour. Texture.	Preparation of working drawings. Application of design. Good craftsmanship. Elements of construction Possibilities, limitations and " finish " of materials.

INDIVIDUAL EFFORT OF STUDENT.

Survey of problem.
Proportion and Fitness.
Decisions in design.
Completeness of expression.
Beauty of finish.

THE PROBLEM OF DESIGN IN THE METALWORK ROOM.

Georgio Vasari the 16th century artist and writer said, " All these lines and works and ingenious arts as one sees, are derived from Design, which is the necessary fount of all, for, if they are lacking in design, they have nothing."

His words express the idea which has animated craftsmen throughout the ages, and to-day they serve to stress the importance of the subject with which we are dealing.

When designing anything, be it mechanism, buildings, a piece of fine art, etc., we arrive at certain conclusions, and make a series of decisions. These decisions are made when the various implications of the problem present themselves, which they do in the following sequence when a piece of metalcraft work is the project under consideration.

DESIGNING PROCESS.

Decision I. ..	.. Discussion of project. Will it satisfy requirements ? Essentials.
Decision II	.. Most suitable material. Has sufficient skill been acquired to work it ?
Decision III.	.. Method of construction. Survey of constructional elements known.
Decision IV.	.. Shape after experiment, and application of rules for determining " ideal " proportion.
Decision V. ..	.. Refinement of outline. Curves, tapers, projections, moulds, turnings, etc.
Decision VI.	.. Decoration Possible types. Border, area, and centre treatment.
Decision VII.	.. Most suitable finish :—burnishing, colouring, lacquering, polishing, etc.

The vague idea of the thing to be made will, by these decisions, have assumed a more specific form, and may now be transferred to paper in the form of a working drawing. The information is to hand for making it, and may be said to be the resultant of teacher effort plus student effort.

Originality which we associate with design may only be developed by this dual effort. Ideas will come spontaneously only to the student who has a sound knowledge of principles, a thorough acquaintance with his material, and the technical skill to handle it. Without that power his productions, intended to have the appearance of originality, will be merely distortions.

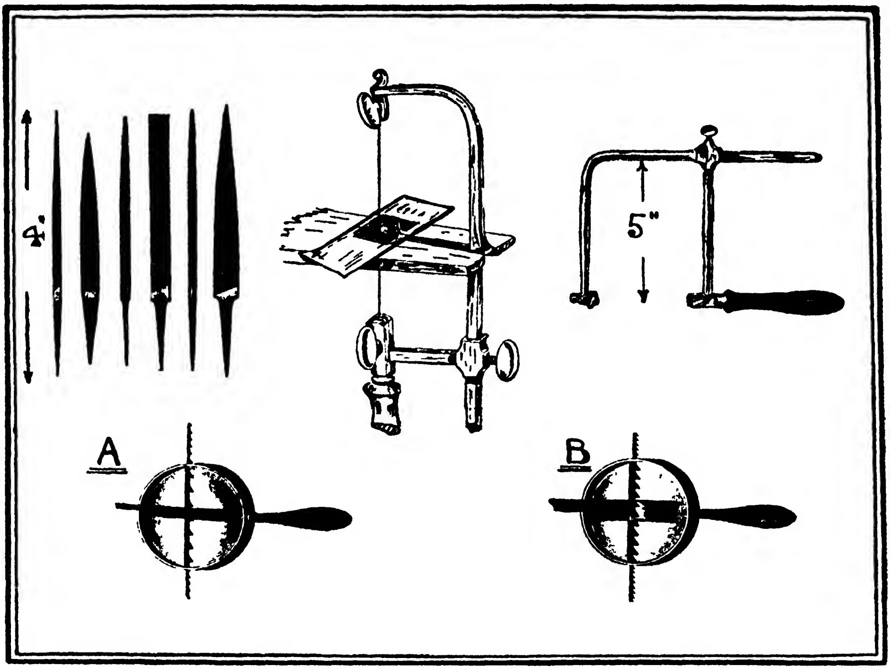


FIG. 88 —PIERCING TOOLS.

PIERCING.

Little equipment is necessary for the ornamentation of metal by piercing. If facilities for drilling already exist, the only tools necessary are piercing saws and a few assorted small files, see Fig. 88.

The jeweller's piercing saw frame should be of the pattern illustrated. The adjustable back not only makes it possible for the blade to be stretched and kept in tension, but it allows of short pieces of saw blade to be used. It is also advisable to select frames that are fairly deep from blade to back, so as to give considerable cutting range from the edges of the work.

American pattern coping saws may also be found serviceable, but as these are not adjustable, broken blades cannot be used, and have to be discarded, a wasteful proceeding when saws cost about 6/– to 7/6 a gross.

Saw blades are sold by numbers, 00 to 6, according to the coarseness and pitch of the teeth. For ordinary handicraft purposes Nos. 2 and 3 will be found to be most useful.

Fig. 88 shows enlarged views of portions of two saw blades. The pitch of the teeth in blade A is too coarse, being greater than the gauge of the metal. This allows the sheet to slip in between two teeth, and in order to make a cut, the whole depth of each tooth must be dragged through the metal.

In the case of blade B at least one tooth is always in the thickness of the metal, and the " bite " can be regulated by the operator.

Metal saw blades for use in coping saws have looped ends which fit in grooves in the frame. The spring of the frame keeps the blade in tension.

The saw blade is always fixed in the frame with the teeth pointing towards the handle, so that the cutting takes place on the downward stroke, as in fret sawing. The sawing table with its vee-shaped notch may be screwed to the bench top, or, if this position should be too low for the piercer when seated, fastened to an upright piece held in a vise. Sawing should be done at a steady rate of about three strokes a second, and for smooth fretting the blade should be kept lubricated by an occasional rub with a piece of bee's-wax.

Copper and brass, the metals most commonly used for this branch of metal-craft, are sold in sheets 4 feet × 2 feet. The cost varies with the gauge, and also with the prices prevailing in the metal market, but it averages about 1/6 per pound.

APPROXIMATE COSTS PER SQUARE FOOT,
COPPER OR BRASS.

S.W. Gauge.	Per lb.	Quality.
	s. d.	
20	1 6	Cold rolled, half hard, with
22	1 9	smooth surface.
24	2 0	

Soft annealed copper is often rough on the surface, and whilst it affords easier cutting, its appearance is never so pleasing for pierced work as that of cold rolled metal.

TRANSFERRING THE DESIGN TO THE METAL.

There are several ways by which the " piercing " may be marked out on the metal. The commonest, and generally the most satisfactory is by means of carbon paper, but, in order to obtain a really good transfer the metal plate should be thoroughly cleaned with a rag dipped in turpentine.

Fixing the design itself to the metal with an adhesive like " Gloy " is sometimes resorted to, but unless this is done well, and the paste allowed to set before sawing is commenced, pieces of the design are likely to come loose with the saw.

The design may also be "stitched" to the metal, a method particularly applicable for bold open work. The drawing is attached to the metal at intervals with sealing wax, and the design is punched through gently with a very fine pointed tool :—the operation is very similar to that of marking out with a dot punch, see vise work. When the paper is removed the outline of the pattern is indicated by the dotted impression, which may be made more distinct by a rub of fine emery powder.

If necessary the design may be filled in between the punch marks with a scriber, tracer, etc.

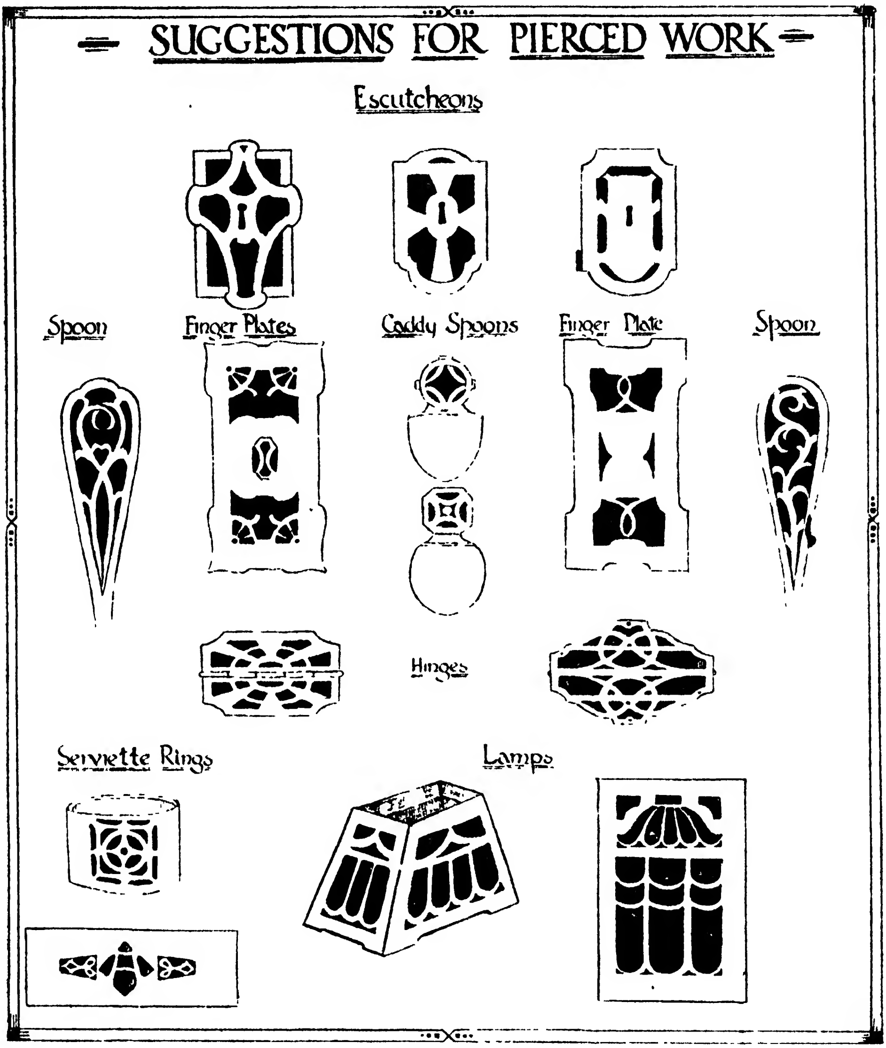


FIG. 89.

PICKLING AND PICKLE BATHS.

Before pierced work, and in fact, any piece of art metal work in copper or brass is "made up" the metal should be made chemically clean, whilst it is in the flat sheet. For this purpose acid baths known as "pickles" must be used, and either of the following are suitable.

No. 1.	Nitric Acid ..	1 part.
	Water	5 or 6 parts.
No. 2.	Sulphuric Acid ..	1 part.
	Water	6 or 7 parts.

NOTE.—When mixing these liquids always add the acid slowly to the water. Never pour the water on to the acid.

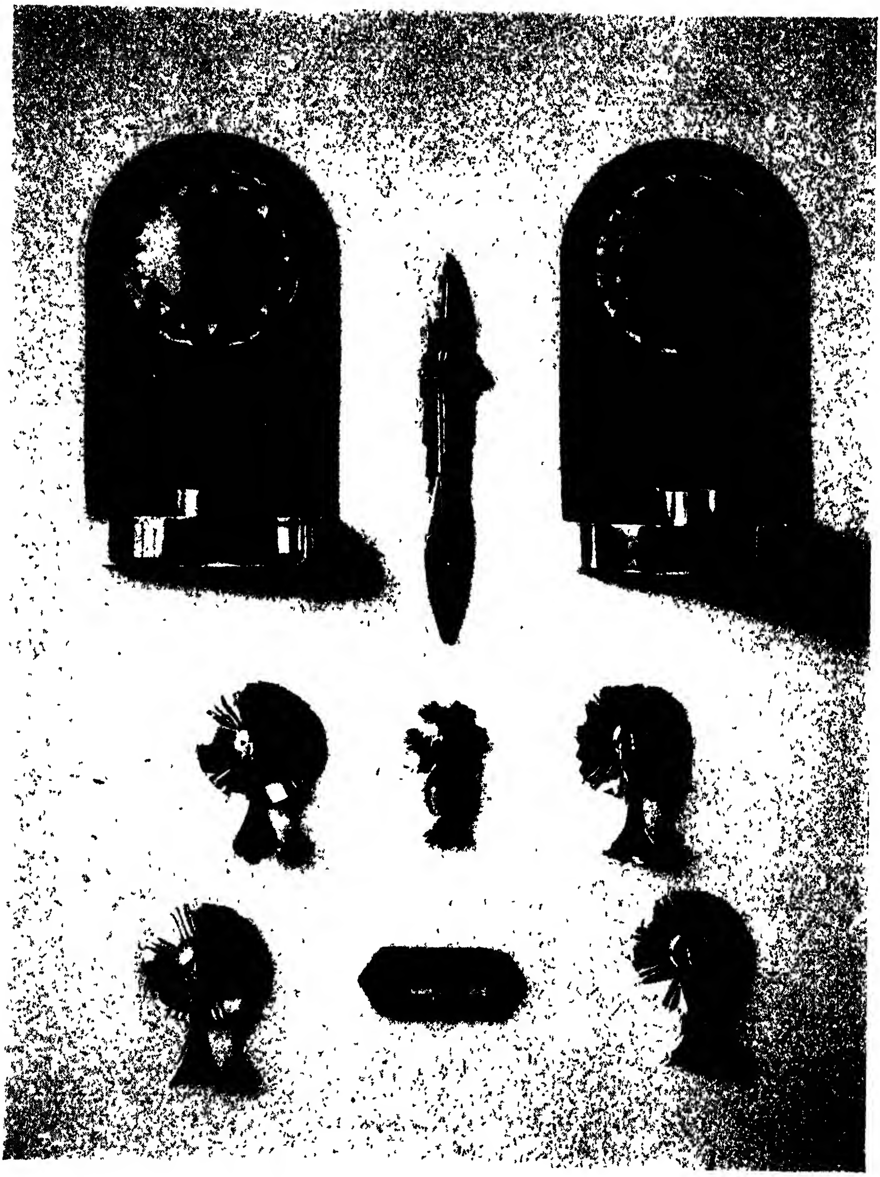


FIG. 90
WORK BY JUNIOR STUDENTS BIRMINGHAM SCHOOL OF ARTS AND CRAFTS.

PRECAUTIONS TO BE TAKEN WITH ACIDS, PICKLES, Etc.

The use of acids to which students have free access in the metalwork room makes it necessary for special attention to be paid to their storage, convenient handling, etc. Pickles may be kept ready mixed in pancheons, or large jars fitted with lids, and stored away under sinks when not in use. A piece of apparatus which has proved very satisfactory consists of a stout box about 20 in. cube fitted with a lid and strong handles. The box contains a jar of pickle, a similar one of water for washing off the acid, and a box of sawdust for drying the metal after immersion. When not in use, the box which is painted and stencilled ACID, is kept under the sink. If spots of acid should splash on hands or clothes its action may be neutralised by the quick application of an alkali, and a bottle of ammonium hydrate should be near at hand when acid solutions are being used.

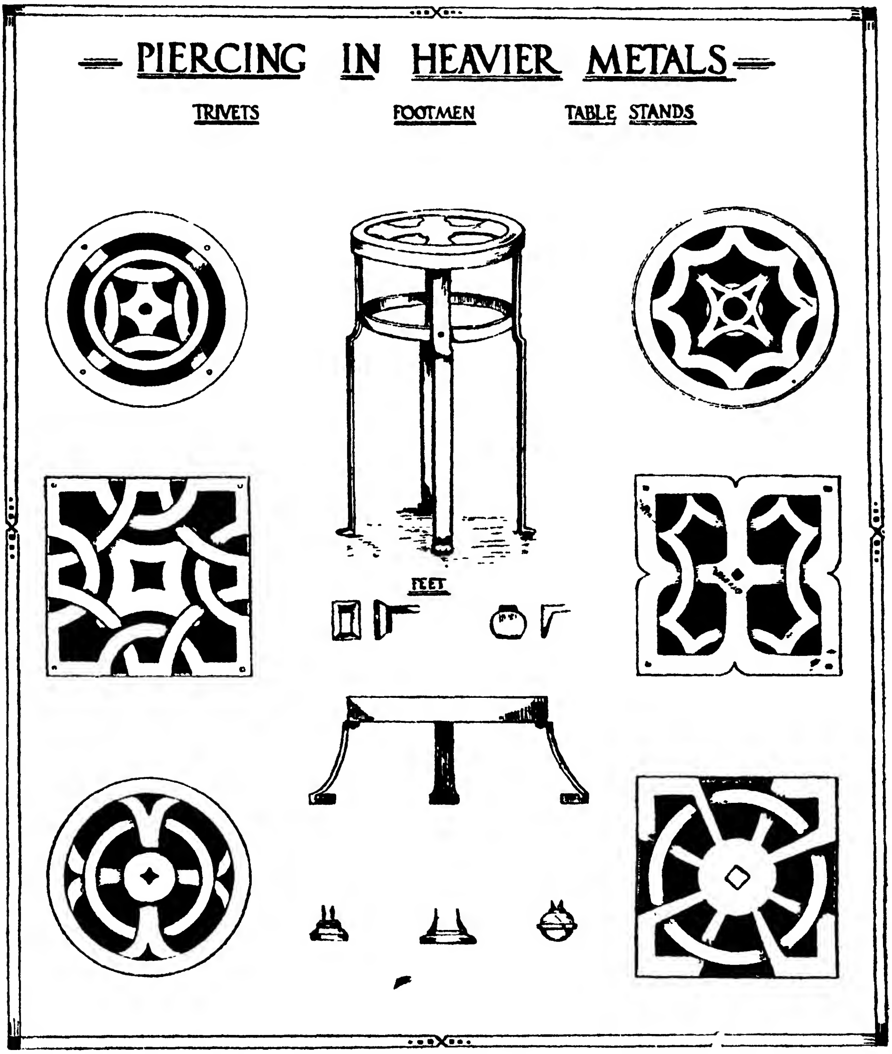


FIG. 91.

For removing work from pickling baths small crucible tongs coated with japan black should be used, steel pliers or iron tongs unless protected produce an objectionable stain on the metal, and their use should therefore be avoided as much as possible.

REPOUSSÉ.

The art of decorating thin sheet metals, chiefly copper and brass, with raised patterns, by means of special punches under the action of a light flexible hammer, is known as repoussé.

There is a quality about this hand hammered work with its variety of outlines, textures, lights and shades, which distinguishes it from the hard lines and dull monotonous surfaces of machine embossed productions.

A similar decorative treatment can be given to pewter, but in this case the metal is so soft that the ornament may be raised by merely pressing with suitable modelling tools, instead of hammering. Pewter is more expensive than copper, a piece 24 in. × 14 in. No. 2 gauge costs about 3/3 and weighs 1 lb., but a preliminary exercise or two to give a student some ideas of high and low relief, introduces a beginner naturally to repoussé methods and tools when the need for them is felt to " push out " the ornament on slightly tougher material.

EQUIPMENT.

Very little outlay is necessary to provide requisite tools and appliances. Many of the latter can be made by students, and after a start has been made with a good set of punches, others may be forged and hardened from cast steel blanks, as the need arises. Fig. 92 illustrates what may be regarded as a minimum equipment.

BLOCKS.—WOOD AND PITCH.

Ornament in low relief, or composed of indented outlines :—borders of finger plates, frames, rims of plaques, etc., may be worked on a piece of hard wood. This wood fixing ground, which should be uniform in texture, and free from knots and shakes, obviates the use of pitch cement, but its use, except in the hands of experts, is limited to the type of ornament referred to. Black walnut and sycamore have been found to be serviceable timbers, both giving sharp clear impressions. Fig. 92 shows a corner of a wood fixing ground with a piece of copper clamped loosely in position with hard wood or metal " saving " strips.

To allow for the slight expansion of the metal during the repoussé process the screws on the strips are kept about ¼" away from the edges, and only screwed sufficiently tight to hold the metal down, but not to prevent it sliding under the strips.

Some repoussé workers work low relief ornament very successfully on lead fixing grounds. A piece of 6 lb. sheet lead about $^3/_{32}$ of an inch in thickness is placed between the metal to be worked and the wood block, see Fig. 92, and being of a more even texture, permits of greater relief over a larger area than wood

Ornament in high relief is beaten from the back of the sheet into the yielding substance of a suitable fixing ground. The ground must be sufficiently firm to support the unraised portion of the sheet, yet soft enough to allow of the metal being "bossed up."

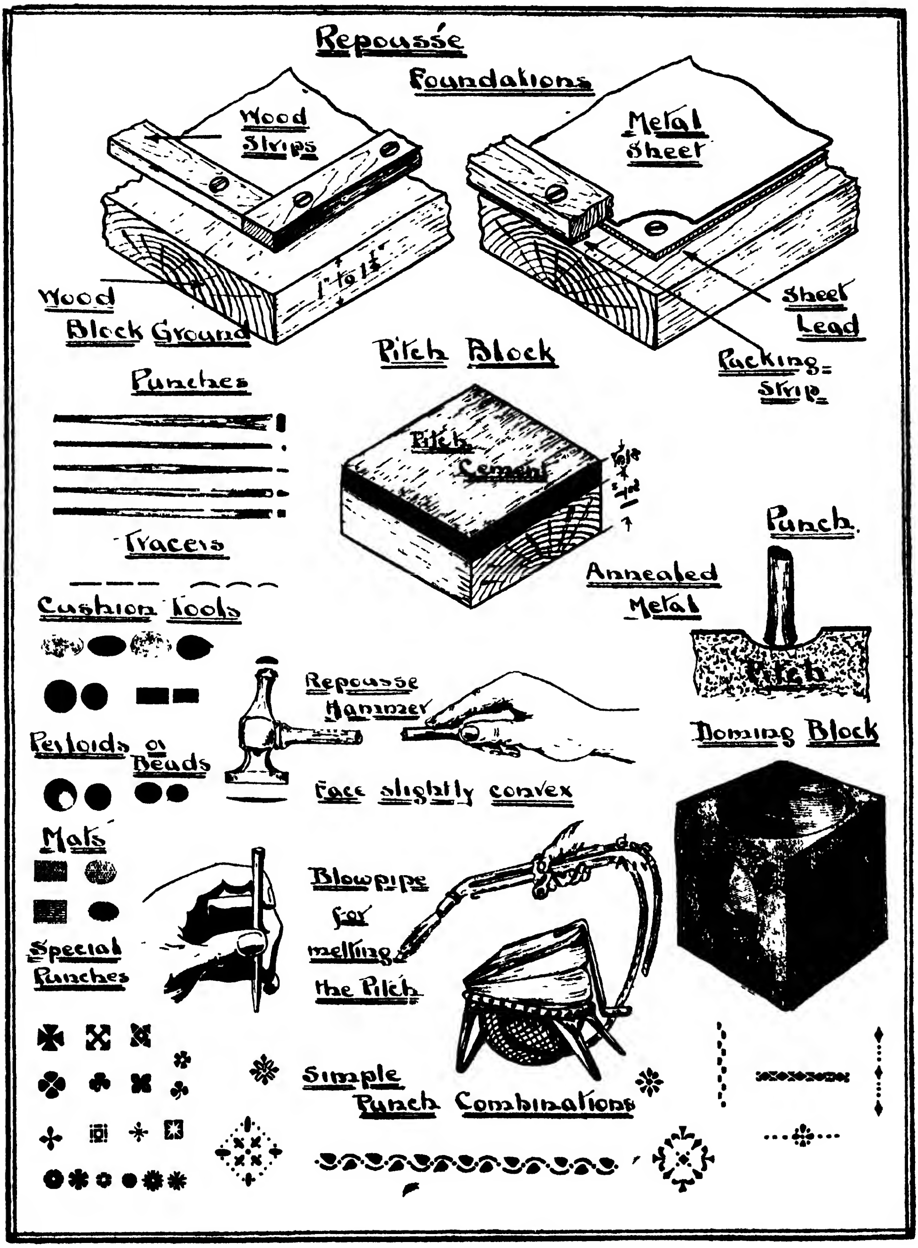


FIG. 92.—REPOUSSÉ TOOLS AND FOUNDATIONS.

These requirements are met by cements of which Stockholm pitch is the chief ingredient.

FORMULA FOR REPOUSSÉ PITCH.

Stockholm pitch ..	..	2 parts by weight.
Plaster of Paris ..	..	1 " " "
Resin ..	.. ..	1 " " "

Tallow, small amount to reduce brittleness. In cold weather the amount of tallow should be increased to give a softer cement.

The pitch is melted first in an old pan, and the plaster of Paris and resin added gradually. Keep stirring, and when thoroughly melted and mixed, add the tallow. Precautionary measures must be taken to prevent the mixture catching fire.

FIG. 93.—PITCH TRAY AND ROPE RING.

The molten cement is finally poured to a depth of about 1 inch into wooden trays to make pitch blocks, see Fig. 92. The size of the blocks varies to accommodate different pieces of work, but a few from 6″×6″ to 9″×9″ will be serviceable.

Pitch cement is supplied ready mixed, and only requiring melting, by dealers in repoussé materials. A larger pitch tray is shown in Fig. 93. It is made of cast iron with a hemispherical projection on the under side. When in use, the hemisphere rests on a thick rope ring, which keeps it clear of the bench. By this arrangement sound is very much deadened, and the tray can be tilted to any angle for convenient working.

Pieces of felt, and loosely filled canvas sand bags are used as cushions under pitch blocks to lessen the noise of hammering.

GAUGE OF METAL.

For ordinary work, annealed copper, gauge No. 20, 22, and 24, will be suitable, the heavier metal being used for large work, and high relief ornament.

FIXING THE METAL ON THE PITCH BLOCK.

The surface of the pitch must be softened by heat, and this is done with some form of blow-pipe, see Fig. 92, but care must be taken not to scorch the pitch or cause it to bubble. Overheating causes the cement to become carbonised, and lose its adhesive property. The metal, with the design marked on it by one of the methods described, and greased on the underside with tallow, is pressed on the softened pitch gently so that all the air underneath it may be allowed to escape. The pressure causes the pitch to ooze over the edges of the metal, and it may be pushed down with the fingers to form a key. To prevent the warm pitch from sticking to them the fingers should be moistened or greased. Pitch blocks should be left in a level position until the cement has set hard.

I. THE REPOUSSÉ PROCESS.

With the tracer, and holding the tool in the manner shown in Fig. 92, indent along the outline of the design. The indented line must be deep enough to show on the reverse side of the metal, and some practice is necessary in order to obtain a smooth continuous dent.

The resiliency of the pitch, and the metal, causes the tool to rebound, and work forward slightly under each tap of the hammer. Skill is required in regulating the blow, or the rebound will be too great, and a series of uneven marks, instead of a continuous line, will be the result.

II. REMOVING THE METAL FROM THE PITCH BLOCK.

The overlapping pitch may be easily chipped away with a chisel, and if the blade is inserted under the metal, it will readily leave the cement if it has been well greased beforehand. Should it not come away easily the blow pipe must be called into use again, and played over the metal. When the pitch is melted the metal may be pulled off with pliers.

Any adhering pitch may be cleaned off by warming, rubbing with oily waste, and applying turpentine.

III. EMBOSSING.

The outline of the design is now indicated by " traced " lines on the reverse side of the metal, and the spaces between the lines have to be filled or " grounded in " with mat tools, as is general in flat work, or, embossed, as in the case of floral forms, leaves, etc., with punches. See Fig. 92.

Whatever treatment is required it must be done in the most direct and simple manner If the metal is overworked by the use of small punches when larger ones might be used, it is liable to crack, and, in any case, it is advisable to anneal before this stage of the work is commenced.

If the raised areas are large and the relief fairly high, a great saving of work may be effected by slightly " bossing up " the ornament to approximate shape on a sand bag with the small end of a repoussé or chasing mallet.

Fix the work on the pitch again, this time with the face downward, and work out the shape of the ornament with suitable punches.

Aim at obtaining the greatest effect with the least tool application.

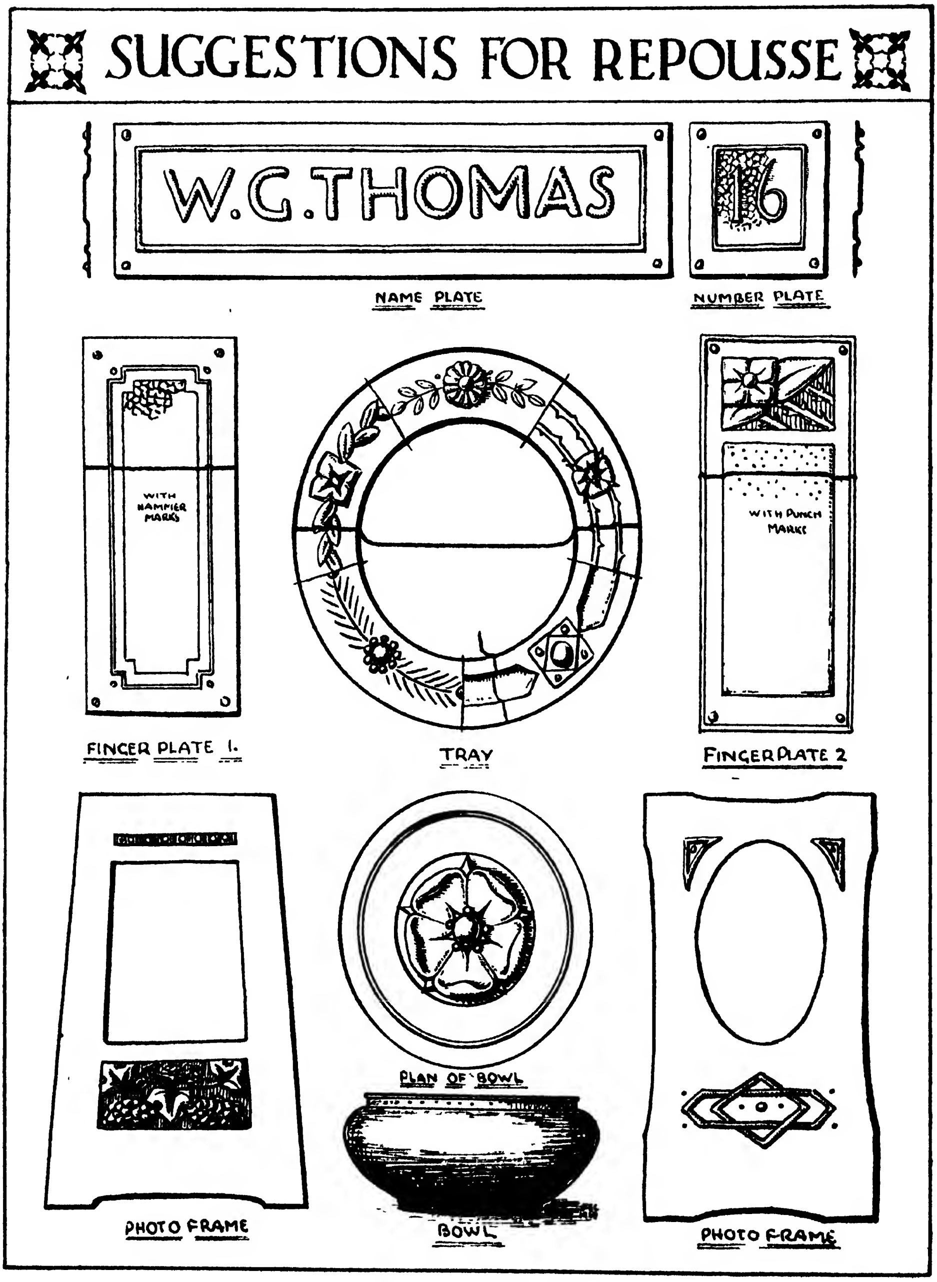


FIG. 94.

IV. MODELLING AND TOOLING.

When the design has been embossed or " pushed down " from the back, to give it sharpness and definition, it is necessary to finally model it on the front face in order to " set down " and in some cases undercut the outline. The tracer is the tool used for this purpose, and the work may be done on a wood block, or, it may be better to again fix the metal on the pitch block, this time, of course, with the embossed face uppermost.

Whichever method is employed it is advisable to fill up the cavities made by the punches, with pitch. This ensures solidity when any subsequent tooling is done. Remember to grease all surfaces well, before they are brought into contact with hot pitch cement.

V. FINISHING, POLISHING, Etc.

As stated in remarks on pierced work, metals used for art metal work should be chemically clean before any tooling is done on them, in order that no oxides may be hammered into the texture of the metal. If this preparatory cleaning has been done thoroughly, no difficulty will be experienced in obtaining a good polish by rubbing pumice powder vigorously over the work with a stiff brush.

For a very fine smooth finish, Water of Ayr stone, which may be obtained in grades, is used, and this may be followed with rouge and a polishing leather. To darken copper to any degree ammonium sulphide is applied with a brush and washed off when the required tint is obtained. Light and shade effect can then be given to the modelling by scouring with fine abrasives like emery powder or any of the polishing media mentioned above.

Finally, slightly warm the work, and with a camel-hair brush apply a thin coat of lacquer to preserve the polish and prevent oxidation.

Fig. 94 shows suggestions for simple repoussé projects.

ETCHING.

The affinity of metals and acids is well known. In some cases the chemical action is most violent, as for instance when nitric acid attacks copper, or sulphuric acid zinc, and unprotected surfaces of these metals are rapidly eaten away. This eating or etching of metallic surfaces by chemical means is made use of in graphic art, as a means of printing, and in industrial art, for the embellishment of surfaces.

The process is a substitute for engraving on metal plates, in which lines are corroded by an acid instead of being incised with a graver. Both zinc and copper plates may be used, but the lines and ornament produced on zinc are not as sharp and clean because of the porous nature of the metal, and for this type of decoration in the metalwork room it is recommended that copper, half hard, and cold rolled, about 20 gauge, be used.

NECESSARY EQUIPMENT.

A few etching needles, see Fig. 95, and for fine lines, various sizes of sewing and darning needles fixed in small parallel handles.

A hand vise for holding the metal when grounding.

Crucible tongs for immersing and lifting the metal from the acid bath.

A burnisher, see Fig. 95, for removing scratches from the metal.

A dabber for spreading the ground.

Porcelain trays as used by photographers.

Etching ground.

Nitric Acid.

Turpentine.

THE GROUND.

The plate to be etched may be painted all over back and front with asphaltum or Brunswick Black, made thin with turpentine, and allowed to dry hard. The nitric acid has no action on these bituminous substances, and only attacks the metal laid bare when the design is cut through the ground with etching needles and tools. The trouble with this covering is that the black is rarely tough enough to withstand chipping, and the lines, instead of being sharp and clearly defined are often furred.

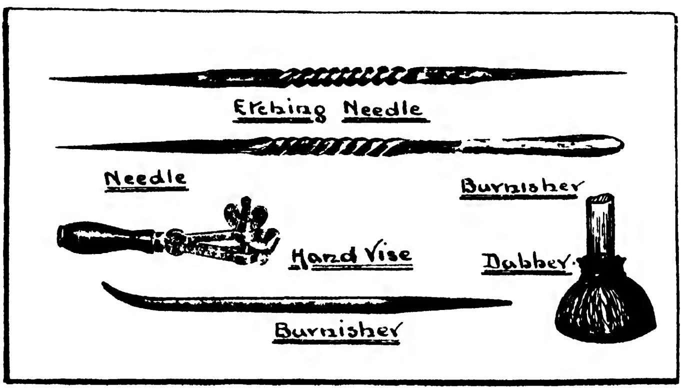


FIG. 95.—ETCHING TOOLS.

Much time and inconvenience is saved by buying prepared ground which is made from asphaltum, Burgundy pitch and paraffin wax, and kneaded into balls about the size of a walnut. The ball, wrapped in silk, melts when pressed on a warmed copper plate, and oozing through the silk covers the plate. To ensure even spreading, a dabber which is made by laying cotton wool on both sides of a disc of cardboard and covering the whole with a piece of fine kid leather, see Fig. 95, is used. An extremely thin layer of ground is sufficient, and when properly laid will be of a golden brown colour through which the sheen of the copper will be seen.

SMOKING THE GROUND.

Again warm the plate from underneath by holding it in a hand-vise, see Fig. 95, over the stove, and when the ground is uniformly melted, allow the smoke from a lighted taper to incorporate itself with it. Care must be taken not to burn the ground with the taper, or the whole process will have to be repeated. Allow to cool, when the plate should present a black polished appearance.

TRANSFERRING THE DESIGN.

If drawn on tracing paper with a soft pencil, the design may be transferred to the plate by the simple process of damping the paper, laying it on the ground, placing a piece of thin cardboard over it, and rubbing the burnisher over it. It is advisable to have the tracing paper bigger than the plate so that its edges can be wrapped round the metal and pasted, thereby preventing movement. On removing the tracing, the pencil marks will be readily seen on the blackened ground.

USING THE NEEDLE.

Very little effort is necessary to cut through the ground and expose the bright copper, but the action of the acid is quickened if the scratch marks are made fairly deep. Needles of varying degrees of fineness are necessary for line work, but where large surfaces have to be exposed, the ground is best scraped away with the point of a penknife blade.

BITING-IN.

When the plate is immersed in the acid bath the duration of the etching process will vary according to the strength of the solution, and the quality of the metal. In a mordant consisting of 1 part nitric acid and 2 parts water a deep biting may be obtained in two to three hours. If the action of the acid is too violent and accompanied by greenish yellow fumes, more water should be added.

FINISHING.

Some experience is necessary to estimate the depth of the biting, but when it is of sufficient depth, lift the plate from the bath with crucible tongs, rinse off the acid, and dry.

The ground and asphaltum may be removed by warming the plate, and rubbing with a cloth damped with kerosine.

The contrast between etched and unetched surfaces may be emphasized by using an oxidising agent such as ammonium sulphide, which darkens the metal, whilst different lights may be obtained with the use of fine emery or pumice powder. A final coat of lacquer for a bright finish, or wax for a softer effect, gives permanency to the surfaces.

Fig. 96 shows a few suggestions for etched ornament.

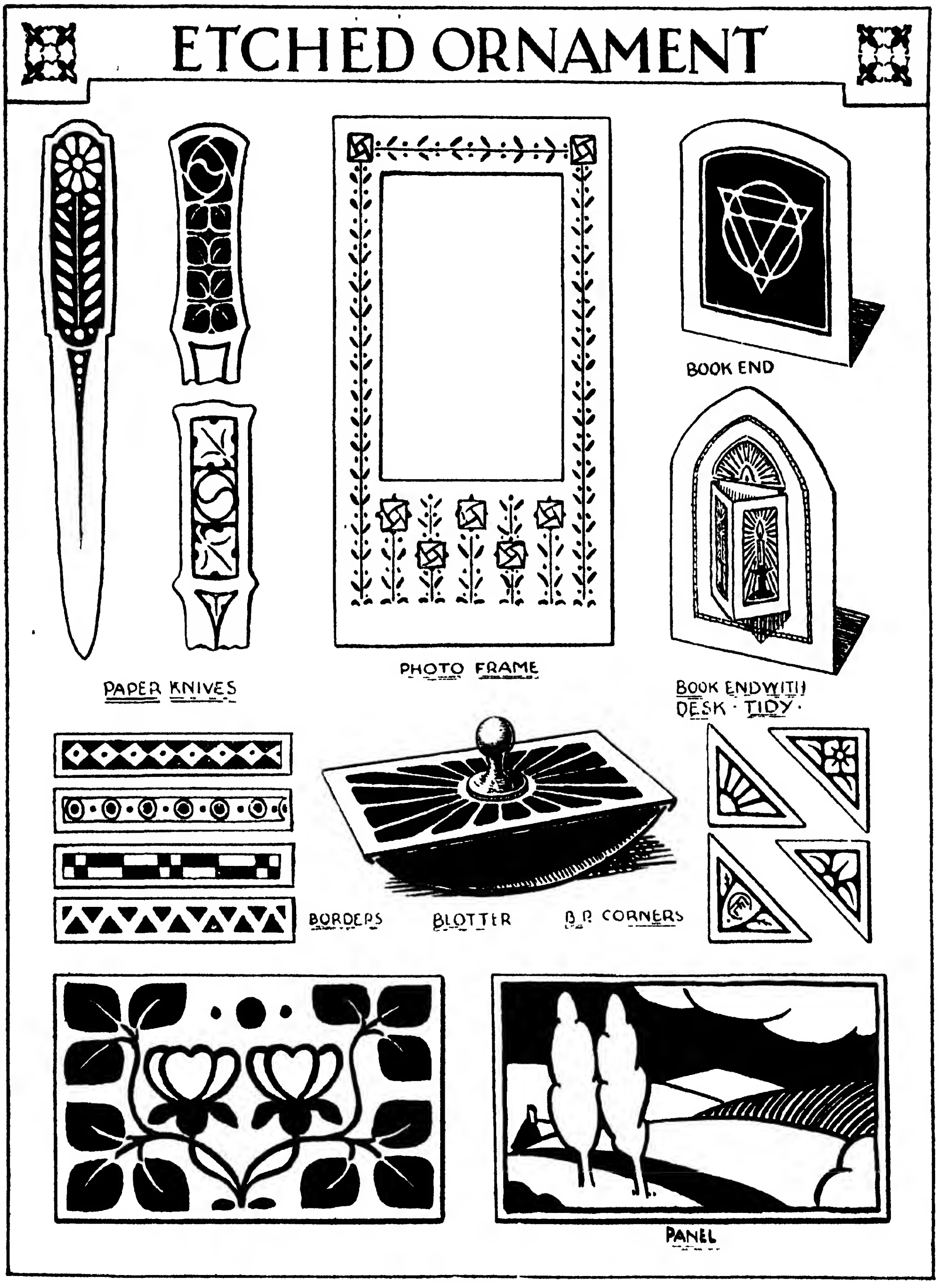

ETCHED ORNAMENT
PAPER KNIVES
PHOTO FRAME
BOOK END
BOOK END WITH DESK · TIDY ·
BORDERS
BLOTTER
B.P. CORNERS
PANEL

FIG 96.

INLAYING WITH SOLDERS.

The inlaying of metal with contrasting metal is one of the oldest of crafts practised by metal workers, and some remarkable specimens of their handiwork are in existence. The precious metals are usually employed, either as the base metal, as in Niello work, in which the design is engraved, and the cut lines and spaces filled with a black alloy, see below, or to form the inlay, as in Damascening, the term applied to metalwork inlaid with gold and silver. Both processes are too expensive to be practised in the handicraft-room, but they suggest a new method of ornamentation by running soft fusible alloys into lines and punchings patterned in copper and brass.

Fig. 97 shows several examples of this type of work.

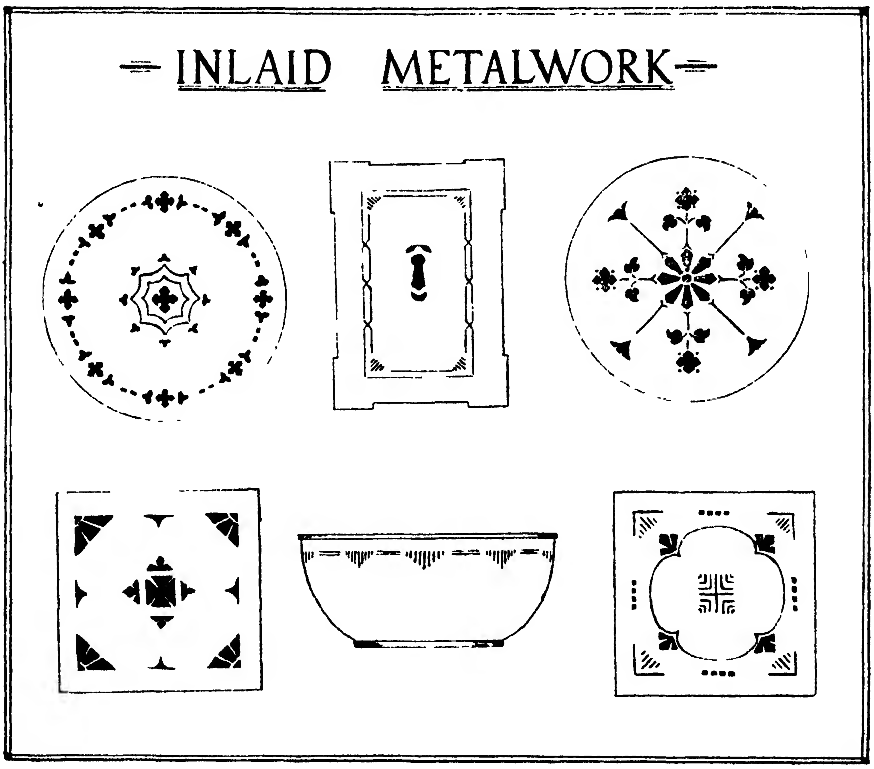


FIG. 97.

Continuous lines are made with tracers, or, better still with a pointed scorper, using it like an engraving tool. If the line is fairly broad it will be possible to undercut the sides thereby forming a key for the metal run in. Designs similar to those shown in the figure, and for which suitable punches have been made, should be transferred to the metal to show the positions of the tool impressions.

Reference to the examples shows that each pattern is built up of simple units, the number of punches needed being few. The shape of each design unit is cut and filed on the end of a steel blank, see Fig. 98. Long screws may be used for this purpose, but if cast steel is used, and tempered after the manner of a repoussé tool, sharper impressions will be made, adding considerably to the appearance of the work.

Each impression in the metal is made with a single hammer blow, and should not show on the obverse side. The plate, which is supported on an iron block, is merely compressed by the punch to a depth of about $^1/_{64}$ inch.

Examples of this " blind tooling " as it is sometimes called, are frequently seen on soft metal utensils, particularly old pewter ware.

Small paillons or granules of solder with flux are placed in the impressions made, and heated over a Bunsen burner or blowpipe; care being taken to avoid an excess of solder spreading over the surface of the plate, as any surplus has to be scraped and filed off afterwards. Various solders may be used for the inlay, to give different lights. The following are all suitable, and readily fused.

Colour.	Solder.	Composition.	Flux.
White inlaid pattern ..	Tinman's Solder ..	2 Lead 1 Tin	Zinc Chloride
" " " ..	Type Metal	65 Lead 15 Zinc 15 Tin 5 Antimony	" "
" " " ..	Pewter	82 Tin 18 Lead	" "
Yellow " " ..	Brazing Spelter ..	50 Copper 50 Zinc	Borax
Black " " ..	" Niello "	2 Silver 2 Copper 1 Lead Sulphur added after the alloy is made granular with a file	Sal Ammoniac or Borax

The " rough " material which overflows the impressions and solidifies on the surface of the plate, must be removed with scrapers and smooth files until the decoration is clearly distinguishable. The surface is then burnished with a hot burnisher, and worked to a fine finish with Water of Ayr stone, then

finally buffed with crocus powder and oil. A heightened effect may be obtained when copper is used by oxidising with ammonium sulphide fumes after the inlaying process is completed.

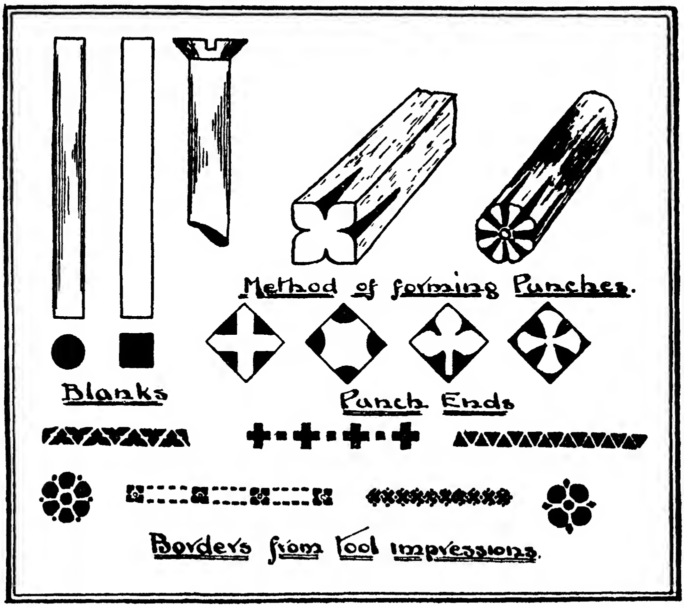


FIG. 98 —PUNCHES FOR INLAID WORK.

WORK IN SHEET AND PLATE METAL.

BOXES AND CASKETS.

Quite distinct from the treatments already dealt with, is the manipulation of sheetmetal, in the construction of trinket boxes and caskets. Their uses are so varied, and the scope offered for initiative so wide, that the interest of students is keyed to a high pitch when the making of these objects is under discussion.

With a knowledge of Geometry, and the technical processes described in Chapter X., little difficulty will be experienced with the development of the pattern, or the folding and joining of the material. Lapped joints are dispensed with, firstly on the ground of appearance, and secondly because the metals used :—copper, brass, silver, pewter, etc., are of stouter gauge. This makes it possible for the corners of boxes to be butt jointed, the pieces wired together securely, and soldered in the internal angle.

The joints of all the trinket boxes shown in Fig. 99 are secured in this way, whilst the casket, illustrated in the same figure, has the rivet introduced as a constructional and ornamental feature, and is fitted with angle pieces which form the legs. No soldering is necessary in this example, except to attach the bottom, but a better job is made if the inside corners are neatly floated with solder.

CONSTRUCTIONAL DECISIONS.

The fitting of push-on lids, and the vexed question of hard or soft soldering, have to be considered.

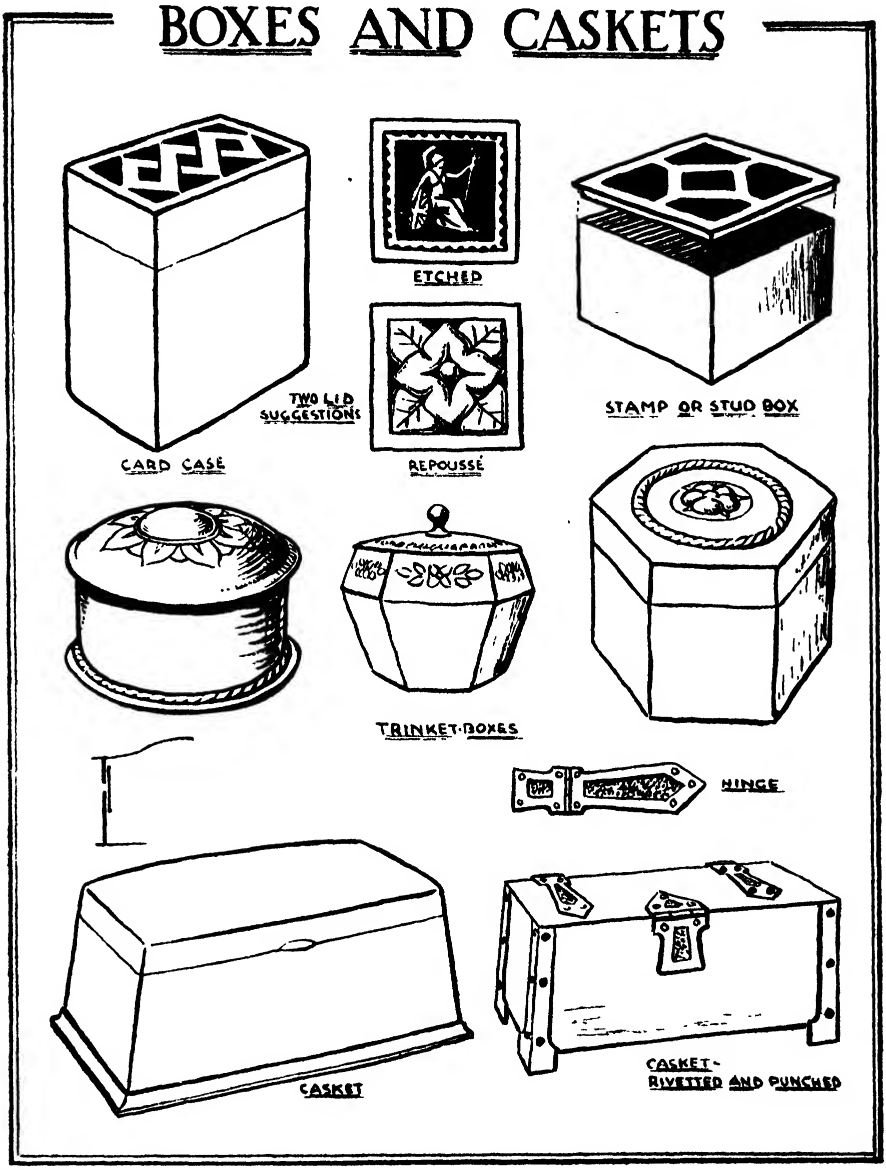


FIG. 99.

The only satisfactory way of constructing a box, as for instance the one for holding playing cards, Fig. 99, in which the top part fits on the bottom, leaving the sides perfectly "flush," is to proceed as follows :—

1. Fold the metal, the full depth of the box, round a wood block mad: the exact size of the interior.

2. Wire round very securely, slip out the block, and solder the loose corner neatly on the inside.
3. Replace the block, fit the top and bottom, wire in position and solder.
4. Mark with calipers, or a scribing gauge, the joint line of the top and bottom sections.
5. Cut through with a fine saw. The reason for leaving the wood block inside is to support the metal during this operation.
6. Solder an inner lining piece, see Fig. 99, inside the lower half, making it project about $\frac{1}{4}$ inch above the joint line to allow the top half to close over it.
7. Complete the fitting of the lid.

In the choice of soldering methods much must be left to individual discretion. Soft soldering is much more readily performed than hard, and is frequently adopted, when, with a little more trouble, better work might be done with the blow pipe.

It may be accepted as a general rule in this class of work, that all initial soldering must be hard, as subsequent heatings would certainly loosen any joining with the more easily fused tin and lead alloy.

DECORATION.

Various forms of ornament are shown in Fig. 99, some of which are familiar. Another effective method for the treatment of edges, and the angle between side and base pieces, is the setting of twisted wire, which relieves the flatness of surfaces, and gives an air of delicacy to the work.

The wire which may be round, square, or rectangular in section, must first be drawn through a draw-plate with pliers, or draw-tongs, see Fig. 100, until it is sufficiently fine for the purpose required. With steel draw-plates, pierced with holes of various shapes and sizes, it is possible to draw the wire to almost any desired form. The device has been used by art craftsmen for centuries, its use having been anticipated by the Egyptians, who made fine strands of gold wire by drawing it through a pierced ruby.

There are numerous types of twists and plaits which the wire may be made up into, a few are illustrated in Fig. 100. The simpler forms will be found to be the most effective, as well as the most easily manipulated.

The boxes illustrated in Fig. 99, are decorated with a double twist:—two strands of wire wound about each other tightly until they present a rope-like appearance, The wire may be twisted entirely by hand, or by rotating the looped end in a lathe, whilst the open ends are held and stretched with pliers. There is a tendency to break the wire by the latter method through overstretching.

Fig. 100, shows a simple twist being made by hand.

Having prepared the wire, a length sufficient to encircle the setting is cut off—erring if anything on the short side. The wire can be lengthened, but never shortened, except by cutting out the surplus material.

The soldering is performed by placing very small paillons of solder along the joint, and heating from underneath. When the solder melts it flows along the joint and secures the wire in position, but for neat work considerable care is necessary in estimating the amount of solder needed, and in preventing it from clogging the twists in the wire.

Another form of box decoration is the setting of stones and enamels in the lids. The round trinket box in Fig. 99, is an example of this; with a simple raised pattern round the setting.

A strip of metal is cut and soldered on to the lid to form a miniature tray of the necessary shape, and after the stone is placed in position, the top edges of the metal strip are worked over slightly to hold it in position: the tool used for this purpose being the burnisher illustrated in Fig. 95.

When all constructional work is complete, any imperfections should be removed with files and fine grades of emery: overhanging edges must be rounded and smooth, and the box made pleasant to handle before being finally polished and lacquered.

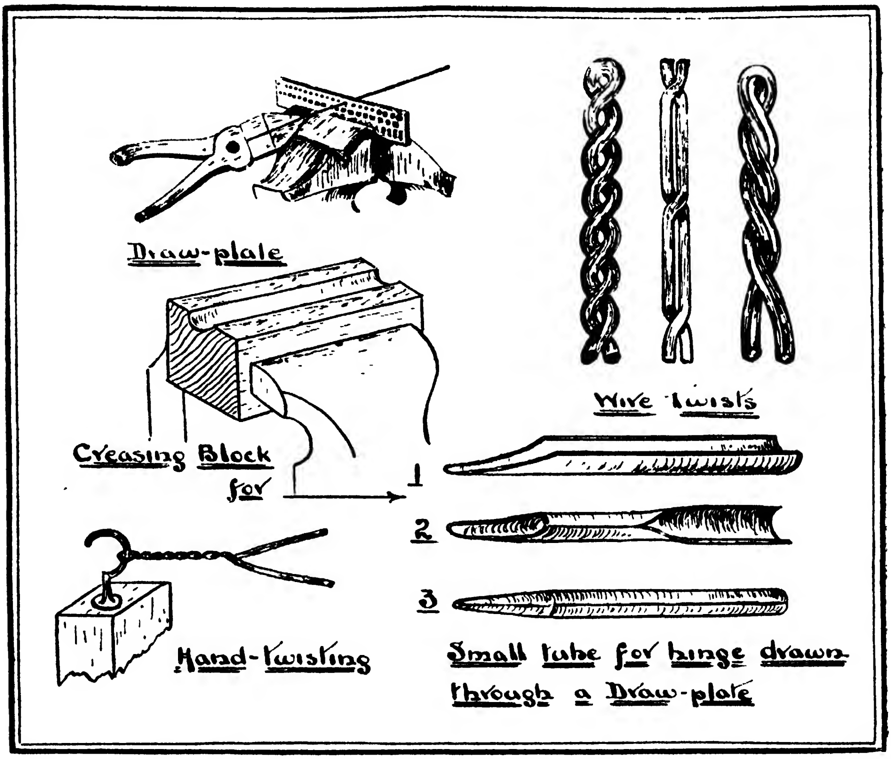


FIG. 100.—USE OF DRAW-PLATE.

IRONWORK.

In contrast to the delicate and fine handling of the tools used in the other art crafts, the manipulation of iron requires vigour and sustained physical effort. Because of this, attention should be paid to simplicity of design, and to the constructional methods it is intended to employ, in order to avoid putting too great a tax on the pupil's power of endurance.

The suggestions in Fig. 101, are examples of ornamental ironwork within the capabilities of students who have attained proficiency in the formal exercises described under Forgework, see Chapter VIII.

Small projects, such as handles, hinges, lamps, brackets, etc., may be made single handed, but group working is recommended for the making of screens, grills, hearth suites, etc., in which the number of recurring details is considerable.

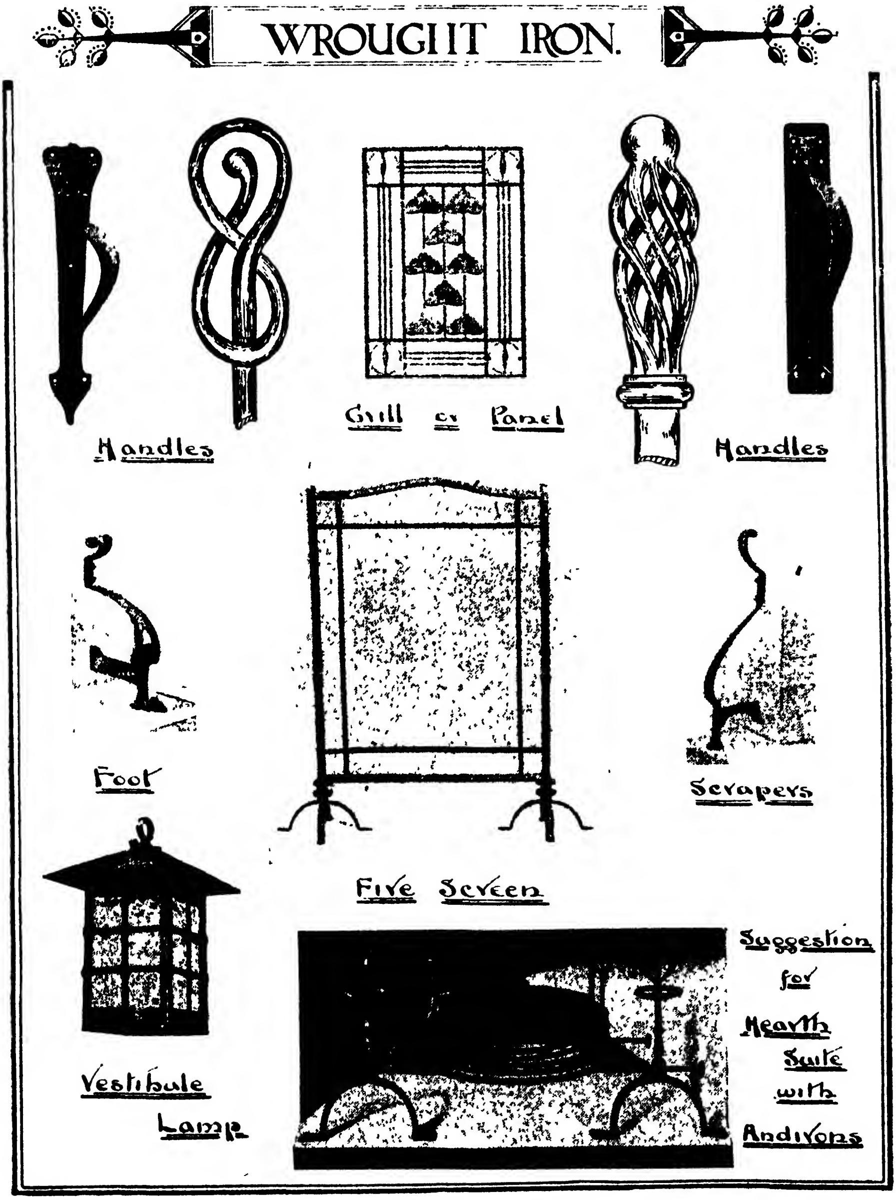


FIG 101

All the regular forging operations :—drawing down, upsetting, twisting, flaring, etc., are carried to a further stage in art smithing; swages and fullers are more frequently needed, and welded joints find a much fuller application.

In pieces of work like the screen and grill (Fig. 101), tenoning is the method adopted for fastening the corners of the frames, and the ends of the inside members. Bars and rods which cross each other are halved together and brazed.

It will be noticed that the use of rivets is made a prominent feature, whilst the introduction of ball headed bolts and nuts for the fastening of feet to uprights, etc., see fire screen, gives an added quality to the work.

The best finish for wrought iron is dull black. When completed, the work should be warmed, and coated with tallow or boiled linseed oil, applied hot. After standing for a day, any grease on the surface should be wiped off, and the surface treatment applied. The preparations now on the market which give a dull cellulose finish are ideal for treating both internal and external ironwork.

"HOLLOWING" and "RAISING" of METALS.

The process of shaping single pieces of sheet-metal is known to metal workers as "raising." Strictly, the term should only be applied to work on which the force of the hammer or mallet blow is dealt on the outside and the metal is being continually compressed, see Fig. 106, as in the case of beakers, bowls, etc.

When metal is shaped from within as in the making of trays, plates and dishes, we use the term "hollowing," "sinking," "dishing," and "doming," see Fig. No. 105. These terms are used somewhat loosely, but in all of them the metal is stretched and the hammering done from the inside. It is frequently necessary to employ both processes on the same piece of work. Special hammers, mallets and stakes peculiar to this type of metal craft are necessary and considerable skill in the use of them together with a sound knowledge of the properties of metals—malleability, ductility, annealing, etc., are essential for successful achievement.

EQUIPMENT.

In addition to the small tools and stakes for sheet-metal working described in Chapter X, the following special equipment is recommended for a group of six to eight pupils :—

HAMMERS.

		Length.		Weight.	Size of Faces.
1.	Blocking	$5\frac{1}{2}''$	..	9 oz.	$\frac{3}{4}''$ diameter
1.	„	$5\frac{1}{2}''$	..	$8\frac{1}{2}$ „	$\frac{5}{8}''$ „
2.	Collet	$4''$	..	4 „ ..	$\frac{3}{4}''$ „ by $\frac{3}{8}''$ diameter.
2.	„	$3\frac{1}{2}''$	..	3 „ ..	$\frac{3}{4}''$ „ „ $\frac{5}{16}''$ „
2.	Raising.	$4\frac{1}{2}''$	..	5 „ ..	$\frac{5}{8}''$ „ „ „ „
1.	„	$3\frac{1}{2}''$	..	4 „ ..	$\frac{3}{4}''$ „ „ $\frac{3}{8}''$ „
1.	Planishing.	$5''$	..	12 „ ..	round $1''$ diameter square $1''$ „
1.	„	$4''$	..	6 „ ..	round $\frac{3}{4}''$ diameter. square $\frac{3}{4}''$ „
1.	„	$3\frac{1}{2}''$	..	5 „ ..	$\frac{3}{4}''$ round both ends.

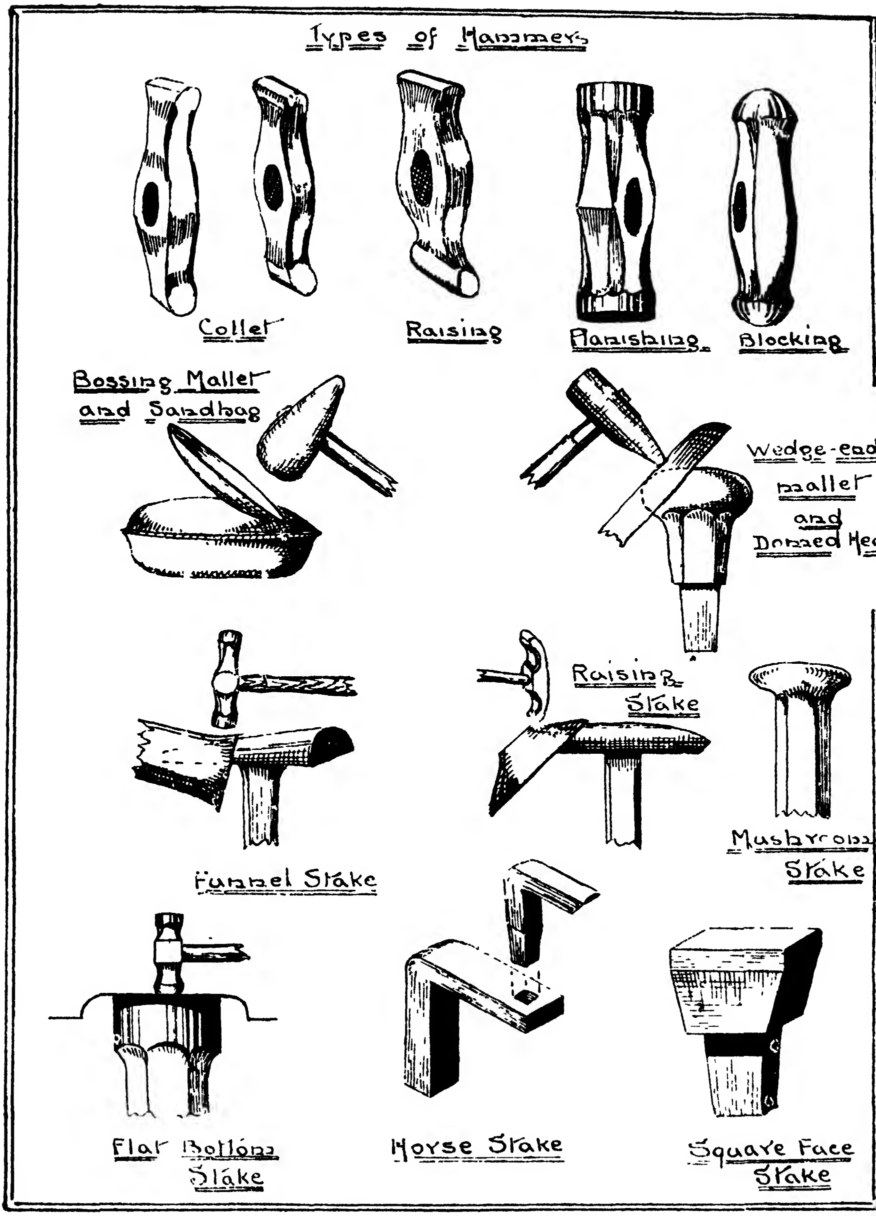
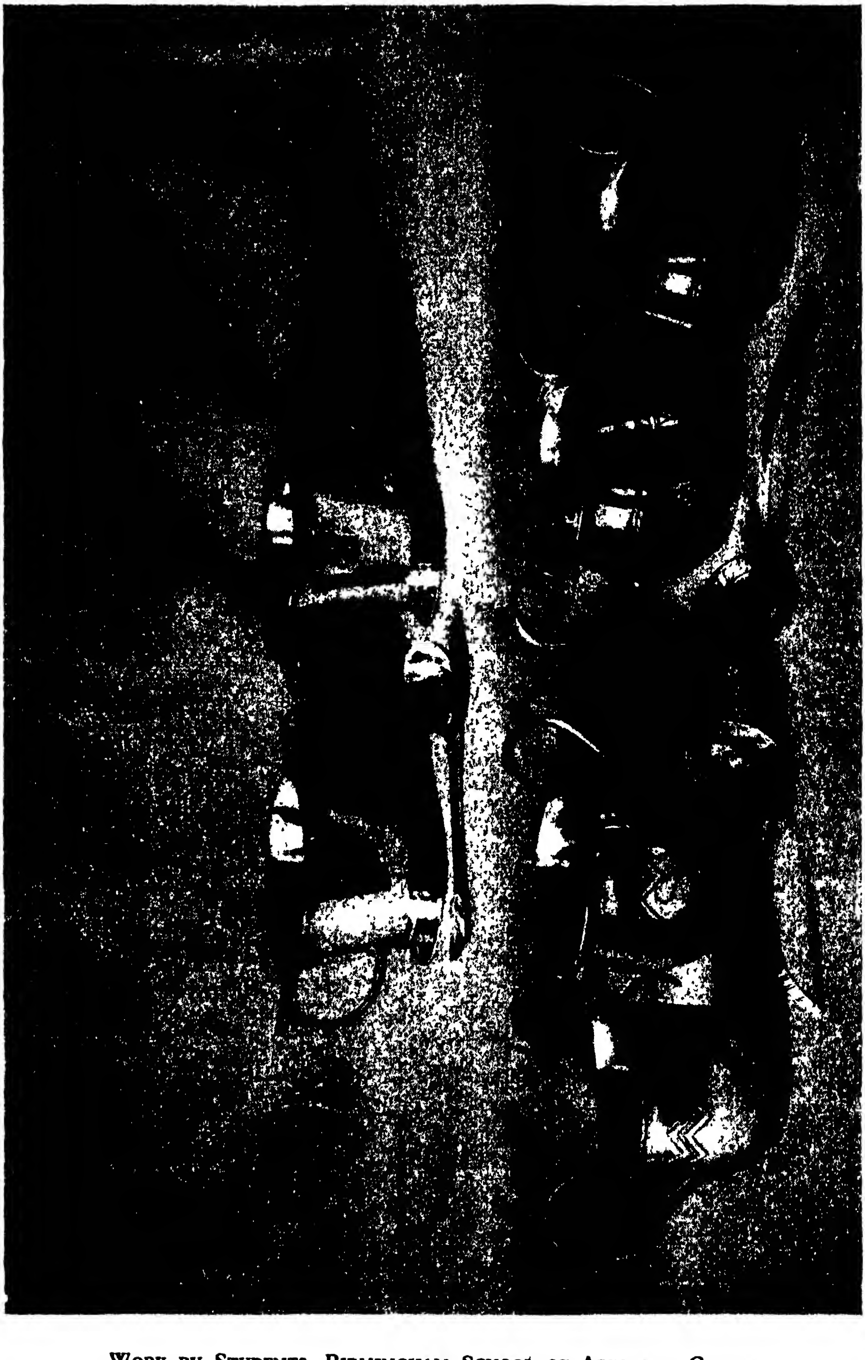


FIG. 102.—RAISING TOOLS AND STAKES.

MALLETS.

2.	Tinman's Boxwood	2″ diameter			
4.	Raising	„	2½″	„	one end wedge shaped
1.	Bossing	„	2½″	„	
1.	„	„	2¾″	„	



Work by Students, Birmingham School of Arts and Crafts.

STAKES.

		Weight.	
1.	Funnel Stake ..	18 lbs.	
1.	Raising " ..	14 "	double arm.
1.	Horse " ..	16 "	single arm.
1.	Bottom " ..	14 "	2″ diameter.
1.	Three-arm Stake ..	10 "	

HEADS.

1.	Square face head ..	3½″ square.	
1.	Mushroom " ..	slightly curved.	
	" " ..	more domed.	
	Assortment of raising heads as required.		
1.	Sandbag	9″ diameter.	
2.	Lead blocks ..	8″ "	by ¾″ thick.

1. Blow pipe with foot bellows or blast and hearth for annealing.
1. Acid bath for "pickle."

An assortment of hollowed wood blocks, mandrils, etc., which will be collected as the need arises.

Note.—The above may be regarded as a minimum equipment with which to commence "raising." It will quickly be added to by tools, particularly hammers and improvised stakes, which can be made in metal-work classes. Collet and raising hammers when first purchased are rarely in a fit condition for use. Their edges are too sharp, and they require grinding to shape and filing and finishing until perfectly smooth. When in good order their ends should be kept bright by the frequent use of spent emery cloth. The recognised standard stakes, beckiron, funnel, flat bottom stake, etc., will have to be purchased, but many of the smaller and special ones may be made from forgings obtained locally. Castings of various heads—mushroom, doming, square face and anvil, etc., may be also obtained in malleable cast iron from patterns supplied.

Much time and inconvenience will be saved in classes if the raising bench is fitted with cast-iron sockets, see Fig. 105a., let in flush with the bench top to receive the tapered ends of stakes and shanks of heads. If the tapers in the sockets and the holes in the horse stake are made the same and the ends of stakes and heads ground and filed to fit, not only will this facilitate easy and rapid changing, but stakes will be much better supported and be more rigid for hammer work than when held in vises.

MATERIAL.

Metal Copper No. 20 S.W.G. annealed, in rolls 1 ft. wide.
" No. 20 " cold rolled, half hard in sheets.
" No. 22 " cold rolled, half hard, in sheets 4′×2′.
Brass No. 14 and 16 S.W.G. for spoons, etc.
Copper wire—round, half round, square and rectangular, small section.

Sundries—
Acids—commercial, sulphuric and nitric.
Ammonium and potassium sulphide.
Soft solder and flux.

Silver solder, various grades.
Borax.
Split cotter pins $1\frac{1}{2}'' \times 5/32''$
Binding wire No. 22 gauge, iron.
Polishing materials.
Emery cloth Nos. 0 and 1, pumice powder, whitening, bee's wax, and turpentine, metal polish.

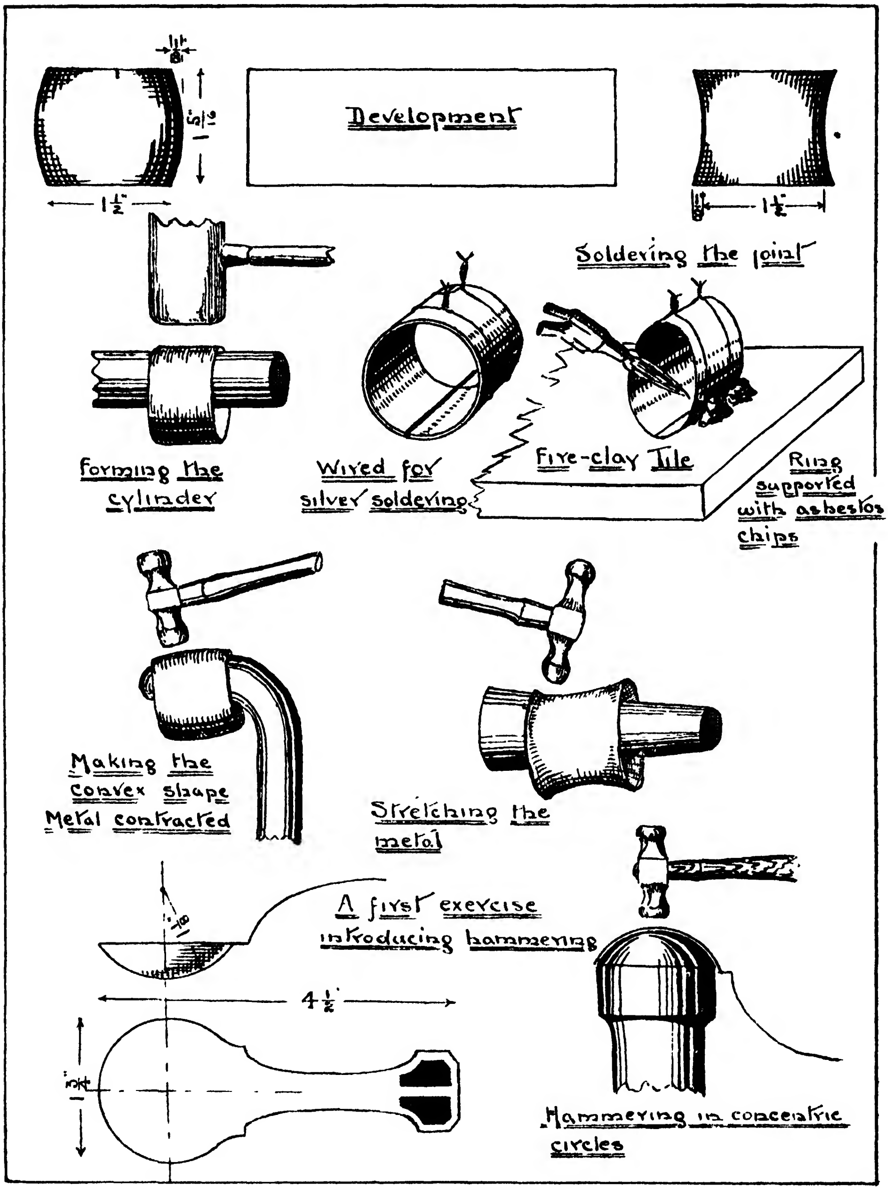


FIG. 103.—HAMMERING.

THE FIRST LESSON. HAMMERING. Fig. No. 103.

To introduce the beginner to the use of the hammer, the correct blow, and point of impact, the stretching and contraction of metals when hammered.

NAPKIN RING.

1. Estimate the amount of metal required for the development of the ring, mark out, and cut a piece slightly larger from No. 20 gauge cold rolled copper.

When cutting with snips cut as close to the line as possible

2. File an edge perfectly straight and smooth with an 8" second cut file, using the file as for draw filing.

3. Mark off the exact length and from the straight edge, square the two ends; cut and file.

4. Mark off the width; cut and file.

5. On a $1\frac{1}{4}$" mandril form the cylinder. To obtain a good butt joint back off the metal very slightly on the inside.

Bind with iron binding wire.

FIG. 104.—A FIRST LESSON IN HAMMERING.

6. Solder the joint with silver solder.
   (a) Brush the seam with borax paste.
   (b) Play a light flame on the ring until the borax stops bubbling.
   (c) Apply solder (a small piece) and heat up gradually until the solder flashes along the joint.
7. Remove the wire, pickle, and file off excess of solder.
8. Again using the mandril make the ring true with mallet or hammer.
9. On a curved stage see Figs. 103–4 and using a 6 oz. planishing hammer, make rings of blows working outwards from the middle. The facets made by the blows should touch each other.

TRAYS and PLATES.

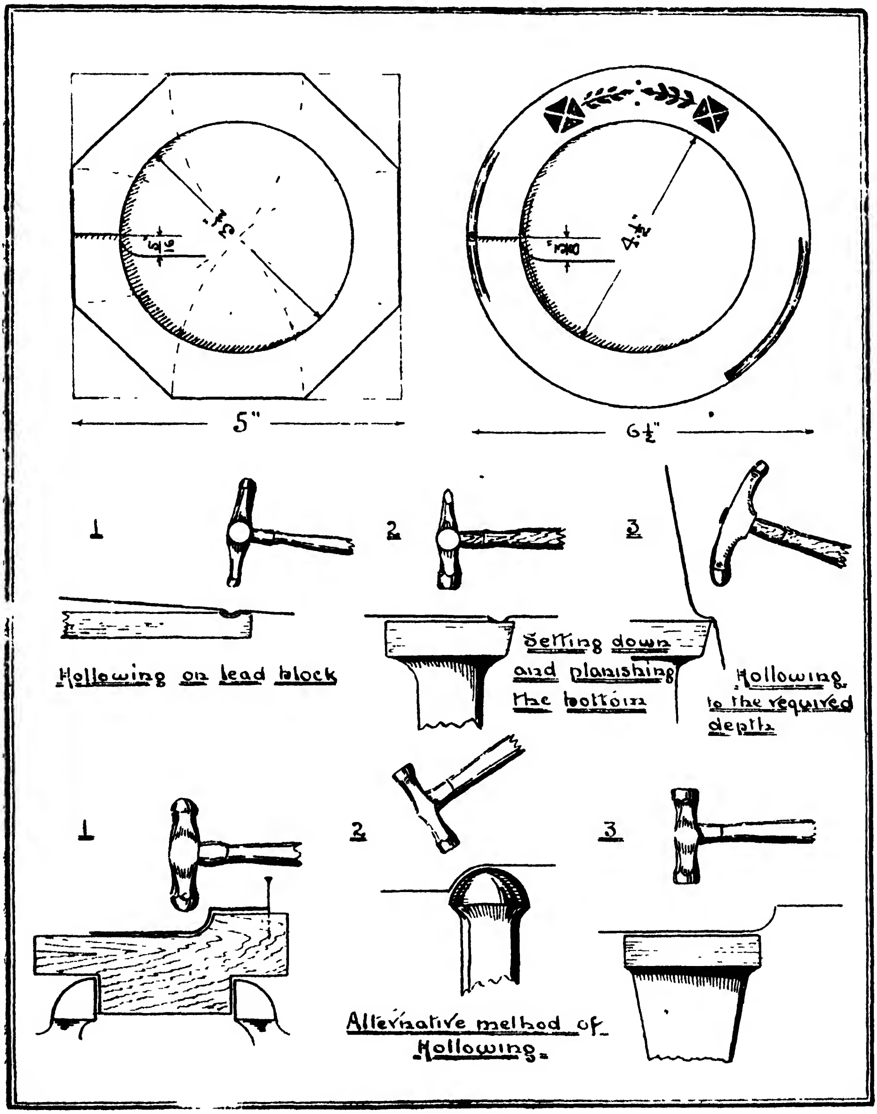


FIG. 105.—HOLLOWING.

10. In this simple exercise the edges of the rings are to be left free, and unsupported, the only stiffening of the metal being that due to hammering. To give the edges a smooth finish they must be rounded with fine files and finished with emery.

11. Clean with pumice powder, and polish on a power buff if available, or if not with metal polish.

12. Colour with ammonium sulphide, and finish by giving a thin coating of wax before polishing with a soft cloth.

HOLLOWING.

A Tray or Shallow Dish.

Material :—Copper, brass or gilding metal No. 20 S.W.G.

1. Cut out a square of annealed material 5″×5″. Very little filing should be necessary on the edges.

2. With wing compasses mark out the sinking line and also another circle ⅜″ inside it. The annulus between the two circles will act as a guide for the hammer blows.

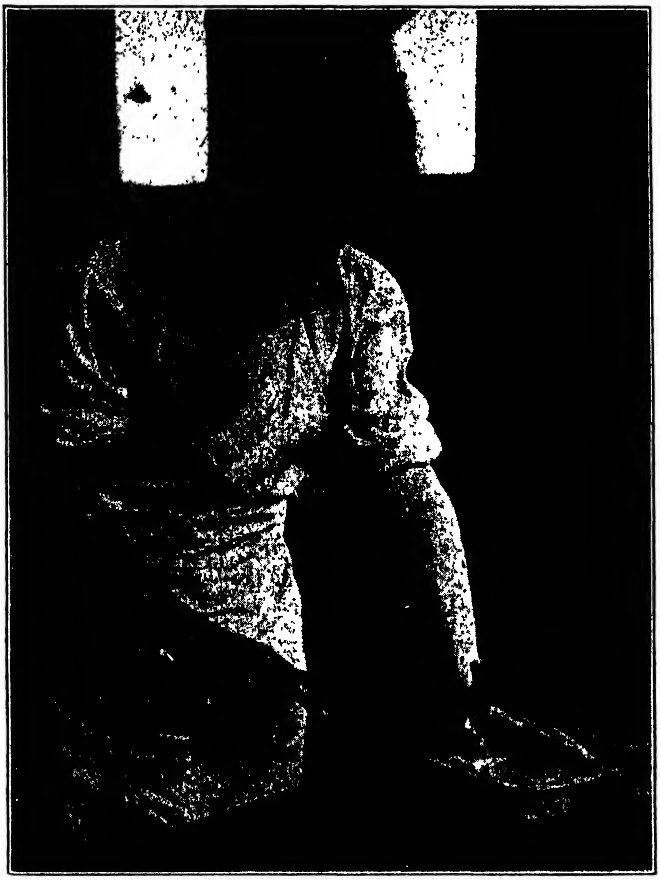


Fig. 105a.—Hollowing on a Lead Block.

3. On a lead block make a slight depression with a $\frac{5}{16}''$ head collect hammer, and using the same hammer drive or sink the metal down into the depression. See Fig. 105 (1), taking great care to keep all the hammering between the two circles.

4. The blank will now appear as at Fig. 105 (2) and the base of the tray must be set down and made flat with a planishing hammer on a flat stake Fig. 105 (3). (A domestic flat iron with plenty of metal in it and the sole worked to a smooth finish, makes an excellent substitute).

The hammering must begin at the centre and be performed in concentric circles working outwards to the sinking line. If each blow is delivered truly the slightly convex face of the hammer will make an impression in the copper, and these impressions should just touch one another and cover the base in a fairly regular pattern.

Fig. 105b.—Flattening the Base.

5. The sunk portion of the tray will now be about half the required depth.

Before making deeper, anneal, pickle, and clean with pumice powder. Place the metal against the side of the square face stake, see Fig. 105 (c) and again use the collet hammer as shown to make the sinking the required depth and repeat stage 4.

6. Sharpen the corner of the sinking with mallet or hammer.

7. By means of a template mark out the octagonal shape and cut with snips.

8. Examine the work to see if the rim is buckled or twisted. If so, correct by inverting the tray on a flatting block of wood or metal, then placing a piece of hard wood on the rim and up against the sinking give a few sharp blows with a heavy hammer.

9. Give a smooth finish to the free edges of the tray with files and emery.

10. Finally clean the surface, colour and polish.

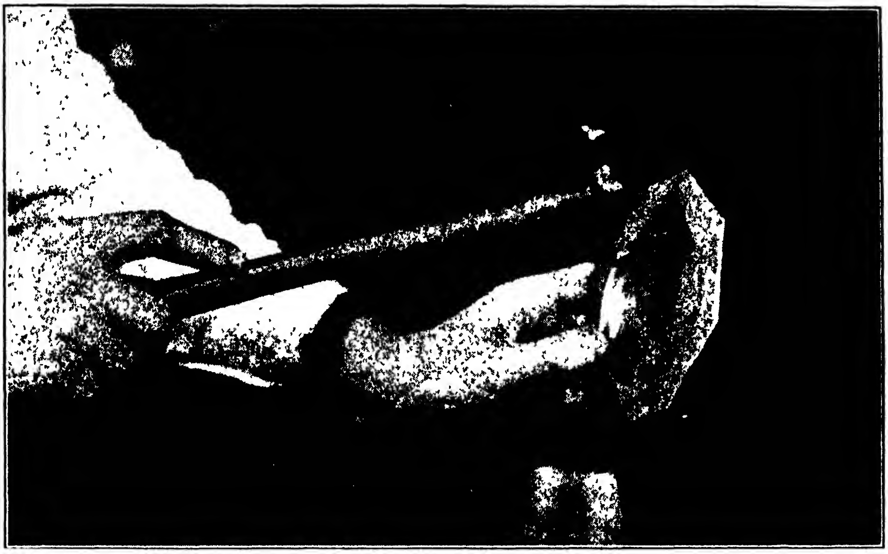


FIG. 105C.—SINKING TO THE REQUIRED DEPTH.

EDGE TREATMENT.

In these early exercises the edges have been left without any reinforcement. For the average student there is plenty of new experience in the hammer work, and by using copper of stout gauge, No. 20 S.W.G., the objects look right for their purpose without giving a sense of flimsiness, but it soon becomes necessary with larger work to finish the edges in a more craftsmanlike manner in order to give strength without adding apparent weight.

The rims of trays and the edges of bowls may be treated both for support and appearance, as follows :—

1. BY FOLDING. The edge of the metal is folded back $\frac{1}{16}''$ to $\frac{1}{8}''$ to form a double thickness. The fold should not be hammered down flat but left slightly rounded, see Fig 49 :—beading an edge, sheetmetal work

2. By Wiring. Similar to above but with a wire inserted to give greater strength and stiffness. One method of wiring a circular edge on a grooved block is shown in Fig. 106. The most common method amongst metal workers is to turn the annealed edge on a half moon stake whilst the metal is slowly rotated. The complete operation is illustrated in Fig. 49.

3. By Reinforcing with wires and moulds of square, rectangular and round section. For circular trays the wire or moulding is fixed in position

BOWLS.

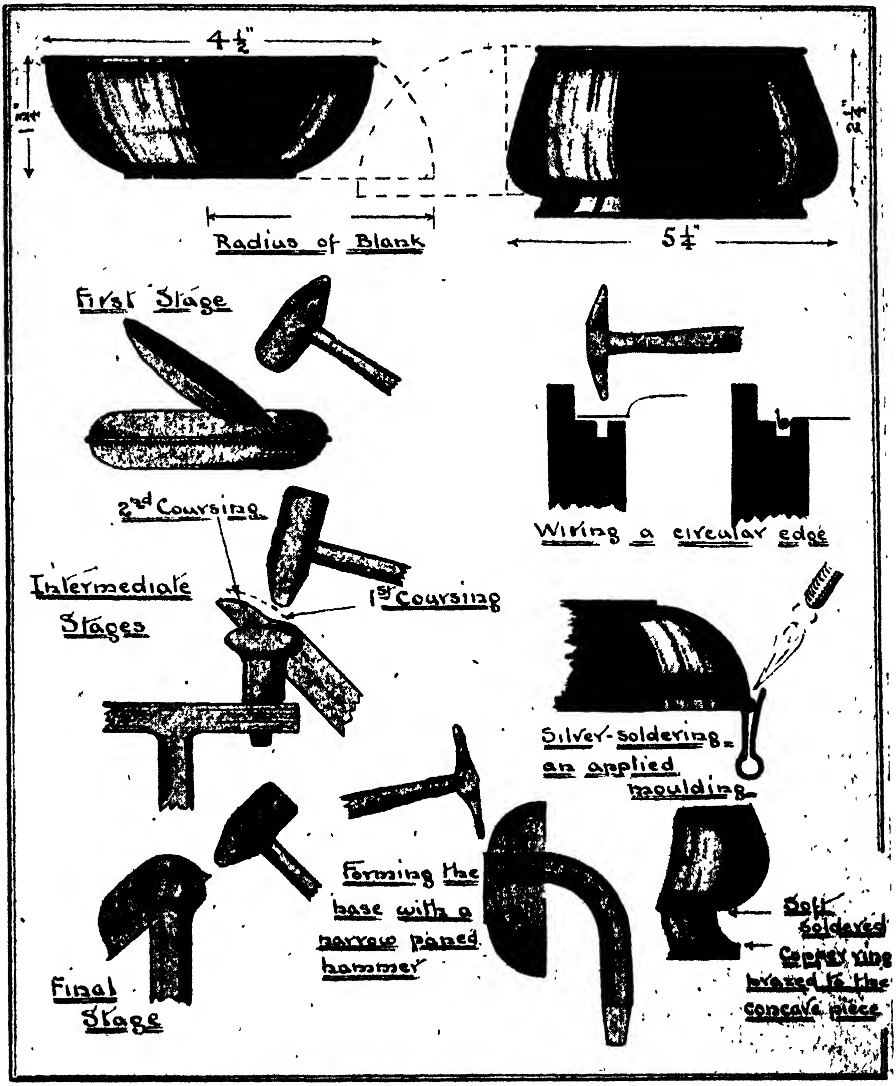


Fig. 106.
Raising with Mallets.
Edge Treatment

with split pins and the ends carefully butt jointed. When fitted together the wire and plate are joined by soft or low fusible silver solder. For the edges of bowls, etc., a ring is made to fit exactly round the circumference with the ends silver soldered.

NOTE.—It is advisable to make the ring slightly less than the circumference of the bowl and then stretch the metal by gentle hammering with a mallet, on a funnel stake. When fitted tightly to the edge split cotter pins are used to prevent the wire from moving when heated.

FIG. 106a.—HOLLOWING ON A SANDBAG.

The bowl is then inverted on a fire brick or small asbestos hearth and silver soldered as shown in Fig. 106.

Any surplus solder left adhering to the work must be neatly scraped off and scratches rubbed down with a stick of Water of Ayr stone before finally polishing.

It the work has been silver soldered it must be pickled to remove oxides, and only copper or nickel tongs should be used to immerse and remove it from the acid bath.

NOTE.—If iron tongs or soft solder are brought in contact with sulphuric acid (pickle) subsequent work, especially if made of brass or gilding metal, will be stained.

RAISING WITH MALLETS.

To Raise a Small Bowl.

1. From the full size elevation of the bowl develop the blank either by the method shown in Fig. 106 or by stretching a piece of string from the top edge round to the middle of the base. The " stretch out " of the string is the approximate radius of the disc of metal required.

NOTE.—It is advisable to add $\frac{1}{4}''$ to the estimated diameter to allow for trimming the top edge of the bowl after the raising is completed.

FIG. 106b.—RAISING A FIRST COURSE WITH A MALLET.

2. Cut out the disc from No. 20 S.W.G. copper.

3. With a round ended mallet hollow the metal on a sand bag, Fig. 106, or in a hollowed block of wood.

4. In the middle of the hollowed disc draw a circle with a diameter equal to the flat base of the bowl, and with the same centre, using pencil compasses, draw concentric circles at $\frac{1}{2}''$ intervals to act as guide circles for the courses.

5. Commencing on a mushroom stake, hold the metal at an angle of 25–30 degrees, with the edge of the base circle just over the stake as shown in Fig. 106, and with a wedge shaped mallet make a ring of blows round the first guide circle.

The blows with the mallet should be delivered slightly above the spot where the metal is in contact with the stake. This causes a pushing action, compressing the metal to a smaller diameter.

The first course is now completed.

Repeat for intermediate courses pushing the metal further forward at each stage.

Anneal when the metal becomes too stiff for comfortable working.

6. Finish the edge on a ball-ended stake with the mallet as shown in Fig. 106.

7. Planish by regular hammering with a planishing hammer on a well fitting stake. The shaping of the bowl being completed, the only purpose of planishing should be to remove any irregularities and produce a smooth surface.

8. On the end of a curved stake and with a paning hammer set down the base. Fig. 106.

FIG. 106C.—PANING DOWN THE BASE

9. Test for truth on a surface plate with scribing block and trim and file the top edge as required.

10. Make and apply the semi-circular wire ring as described in " edge treatment."

11. Scrape away surplus solder, clean and polish.

RAISING WITH HAMMERS.

This method of raising is quicker than by mallet, but great care is necessary to prevent damaging the surface of the metal. Hammered forms also require more planishing than those raised by mallets. The choice of method is determined by the skill of the student, the shape of the work, and the tools and stakes available.

TEA CADDY.

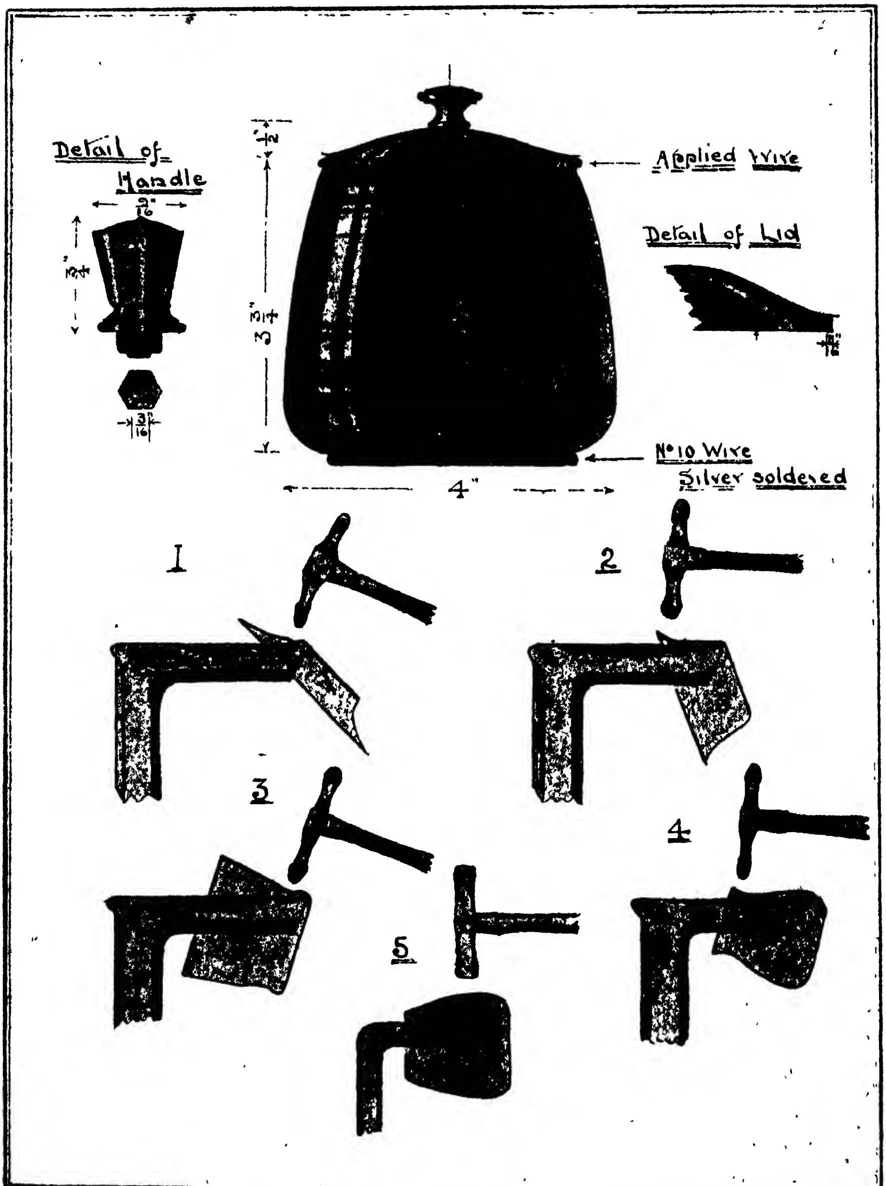


FIG. 107.—RAISING WITH HAMMERS.

A general rule is to use mallets on forms wider at the top than the base, and hammers on forms narrowing in diameter as they are made deeper. The tea caddy or tobacco jar Fig. 107 is a good example of raising by the hammer method.

FIG. 107a.—RAISING WITH A HAMMER.

TEA CADDY.

1. Estimate the size and cut out a disc of No. 20 S.W.G. copper. On the under side mark out the base circle, and with pencil compasses or blunt dividers draw a number of concentric circles to serve as guide lines for the hammered courses.

2. Hollow the disc on a sandbag until it becomes saucer shaped.

3. Invert the shape over a suitable stake as shown on Fig 107 and raise the body. The stages 1 to 5 are shown in the figure. Each hammer blow is directed a little ahead of the point of contact of metal stake and proceeds in courses from the base until the edge is reached. The shape is reduced in diameter and the copper will become hard and more difficult to work. Frequent annealing, pickling and scouring clean will be necessary.

4. Planish the base on a round bottom stake and the side on a " head " as shown at 5, Fig. 107.

5. Apply wire rings to the top edge and base. Clean off and polish.

6. Cut out and shape the lid by hollowing. When finishing to size allow the edge to project slightly over the body as shown.

7. Make a ring of copper $\frac{1}{4} \times$ No. 18 S.W.G. to fit easily in the body and silver solder it to the lid.

8. Turn a suitable knob in brass, copper, aluminium, or ebonite and attach to the lid.

9. Clean off, colour with sulphide solution and polish

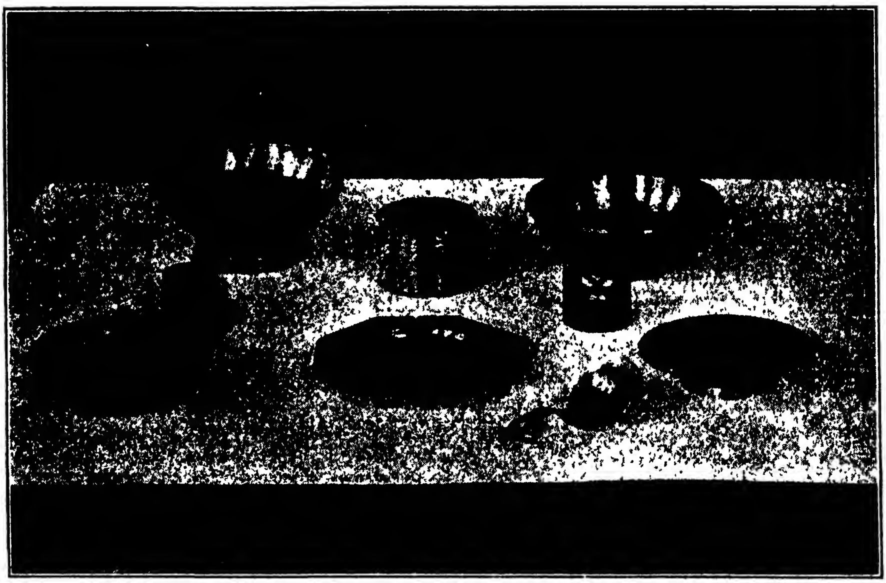


FIG. 108.—A COURSE OF RAISED WORK.

RAISING IN SHEETMETAL WORK COURSE.

Decorative metal work and particularly raising has become a marked feature in modern handicraft courses. The usual practice is to divide the sheetmetal course into two sections (a) geometrical, and (b) decorative (see Schemes of Work). The latter section commonly referred to as Art Metal work, a very unsatisfactory designation, has created a new interest in metalwork classes, affording as it does unique opportunities for developing hand skill, and the expression of æsthetic taste.

Reference to the syllabuses and examination papers in the Appendix will show that it is now necessary for students in teacher's training classes to have worked a course in raised work as a preparation for examinations.

Fig. 109 shows an introductory course which has been successfully worked in teacher's classes for the City and Guilds qualification.

The working drawings of the course are reproduced in Fig. 110.

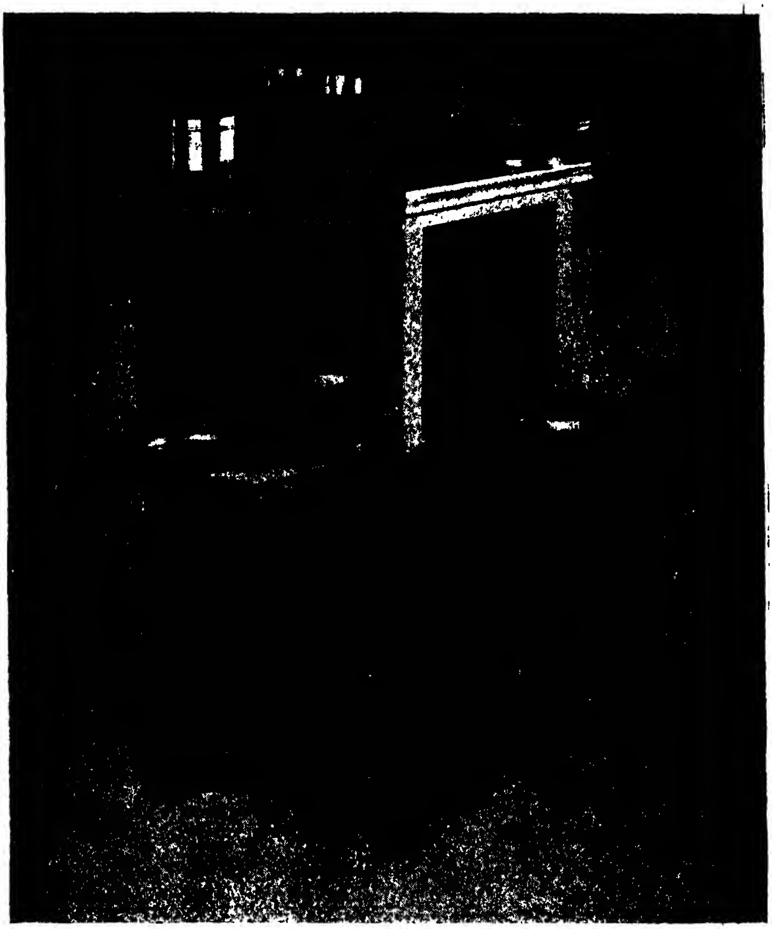


FIG. 109.

BOOKS FOR REFERENCE.

Art Metalwork with Inexpensive Equipment: A. F. Payne.
Educational Metalcraft: P. W. Davidson.
Silverwork and Jewellery: H. Wilson.
Metalwork for Craftsmen: Hart and Keeley.
A First Book of Metalwork: B. Cuzner.
Hammered Metalwork: T. Franklin Evans.

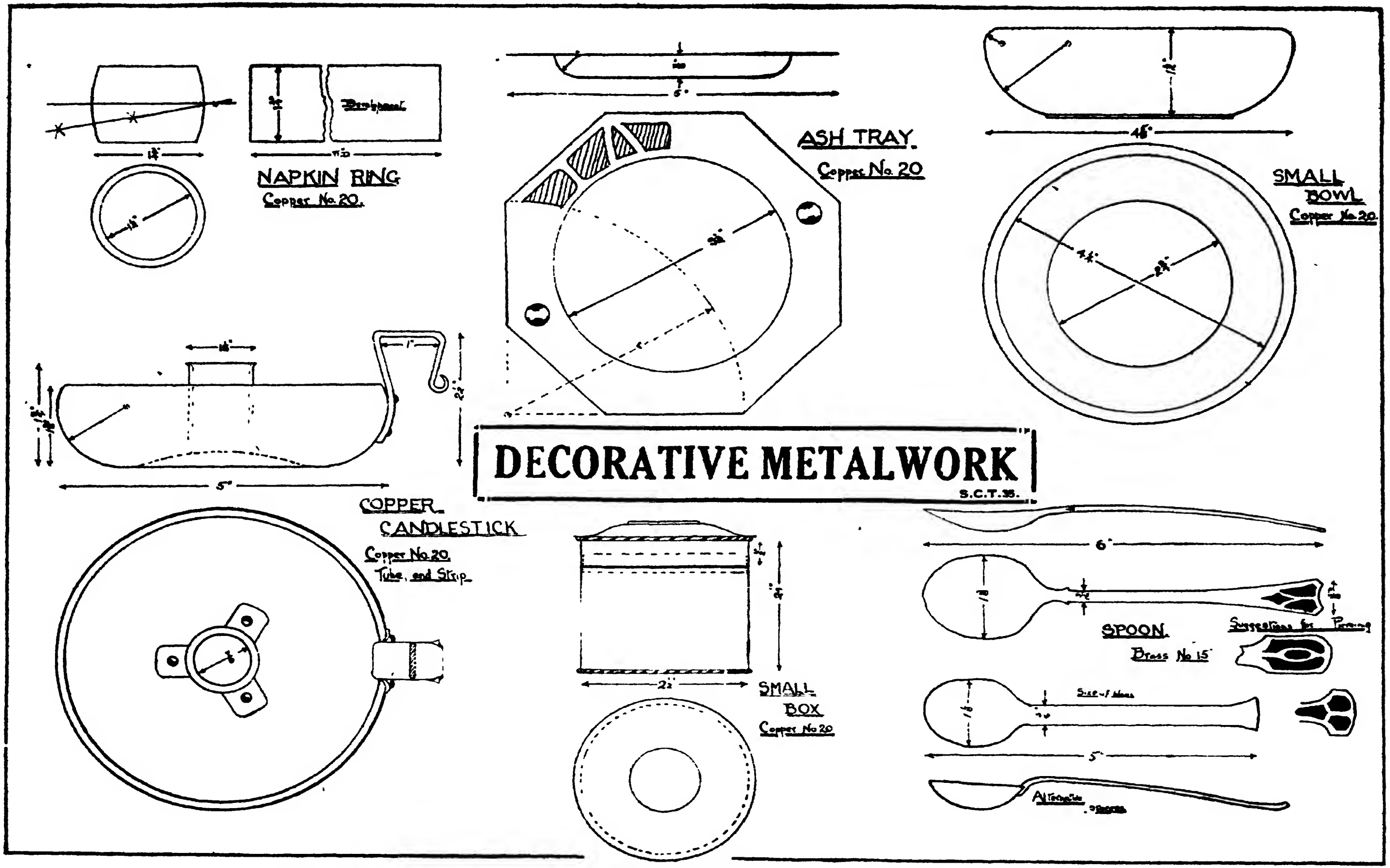


FIG. 110.—AN ELEMENTARY COURSE IN RAISING AND CONSTRUCTIVE METALWORK.

CHAPTER XV.

The "Finish" of Metallic Surfaces.

Polishing. Burnishing. Colouring. Lacquering.

POLISHING.

THE polishing process is nothing more than a matter of scratching the surface of the metal; the large and deeper scratches being removed by finer ones, until finally they become microscopic. Fine files would produce a more or less smooth and uniformly scratched surface, and varying grades of emery would improve upon these results with a series of finer cuts.

Crocus powder and rouge, which are forms of oxide of iron, reduce the scratches to a minute scale, and chalk, whitening, lime, and putty powder (oxide of tin) advance the work to any practical limit.

All these abrasives may be used as powders or pastes, but it is important to use a separate cloth for each grade of polishing agent. Nothing is gained by rubbing with a fine powder on a cloth which has previously been used for a coarser preparation. Deep impressions will constantly be occurring, produced in exactly the same manner as "pinning" marks are scored in metallic surfaces by particles of material becoming embedded in the teeth of files. A separate cloth should be used for each polishing medium.

MACHINE POLISHING.

A polishing bob and mop which may be mounted on the end of an emery grinder spindle, for buffing and finishing, will be found a useful and almost indispensable addition to a metalwork equipment. Bobs are made of leather, or wood with a leather facing, and are treated with emery powder.

Mops consist of discs of soft calico or linen bound together by a leather stock which screws on to the machine spindle. The discs are stitched circularly, and are procurable in diameter from one inch upwards.

The rim of the disc against which the work is pressed, is treated with a paste made from Tripoli powder and wax, or with bar emery. Both are graded so that a cutting effect is produced with the coarser grades, whilst polishing effects attend the use of the finer material.

BURNISHING.

Burnishing is a special art, and experience alone brings perfection. In the metalworking trades, experts, most of whom are women, are said to be "born burnishers."

The tools which are made entirely of steel, or tipped with agate, must be kept in perfect order, and they require buffing frequently on a mop with putty powder.

When polishing work by this method, the tool is held in the right hand, and pressed on to the work in a slanting position. Using a soap lubricant (many burnishers use stale beer), to allow of easy motion, a forward and backward movement is given to the tool until the whole of the surface has been covered. This combination of friction, compression, and spreading, imparts a brightness and compactness to the metal under treatment, which has a quality of its own, being quite different from the polish obtained by the use of abrasives.

COLOURING OF METALS.

There are four methods of colouring metals.

I. MECHANICAL.

In which pigments and coloured solutions are applied to metallic surfaces by painting or dipping.

A succession of colours, due to films of lead sulphide, and ranging from light brown to black, may be produced on the surface of polished iron or steel, by painting with the following solution, and heating to about 200° Fah.

Lead acetate	1 oz.
Sodium thiosulphate ..	1 oz.
Water	2 quarts.

Ironwork may be made a rich black by coating with a solution of :—

Sodium thiosulphate ..	4 oz.
Water	3 quarts.

Several applications may be necessary in order to obtain uniformity of tone. When this is obtained rinse the work, thoroughly dry, and lacquer.

ARMOUR GREY ON IRON.

Rub the bright metal with a piece of blue stone (copper sulphate), and immerse it in a bath of :—

Ammonium sulphide ..	6 oz.
Water	1 quart.

When the required shade is obtained, rinse and dry quickly ; polish with wax, or apply a coat of lacquer.

II. THERMAL.

The film of oxides produced on the surface of steel with the rise in temperature during the tempering process is an illustration of the heat method of colouring metals. Most metals may be similarly treated, but copper is an outstanding case, and some beautiful red to brown oxides are formed when the metal is heated slightly.

At a high temperature the oxide is black (cupric oxide).

The disadvantages of this simple method of colouring are the lack of permanency, and unevenness of tone, although the former may be overcome to a great extent by waxing or lacquering.

III. CHEMICAL.

The most commonly applied method, in which films of colour are produced by the combination of the metal with some chemical substance, and a definite chemical change is brought about.

When copper, for instance, is brought in contact with soluble sulphides of ammonium or potassium, the surface of the metal is converted into copper sulphide, CU_2S (copper glance).

Nut Brown on Copper.

Dry Process.—Suspend the work in a fumigating box which is fitted with a pane of glass in the lid so that the colours may be observed, place a small quantity of ammonium sulphide in a tin vessel over a spirit lamp in the box, and seal the lid. The fumes from the sulphide will soon produce a fine velvety brown, the shade varying with the time of the fuming action.

Wet Process.—This is quicker than the last process, and needs little preparation, the work being merely passed through a cold solution of ammonium sulphide. Only a weak solution is necessary :—about 2 oz. of the chemical to 1 quart of water, but as soon as the required colour is obtained, the liquid should be quickly washed off, and the work carefully dried. The surface colour is easily rubbed off, but may be fixed with methylated spirit, before a coat of lacquer is applied.

Bronze Colour on Copper.

Very rich brown shades may be obtained with the following solution :—

Potassium sulphide ..	½ oz.
Ammonium ,, ..	⅛ oz.
Water	1 gall.

The cleaned work is immersed in the cold solution for a few seconds, until the desired shade is obtained. After rinsing and drying, it is either wax-finished or lacquered.

It is impossible to say with any degree of certainty how brass will behave in the variety of solutions available for colouring it. The alloy is of such variable composition that difficulty may be experienced in obtaining the desired shades, and the colours produced may not agree with those which might be anticipated.

Ammoniacal solutions and brass have a great affinity for each other, and the oxides deposited on the surface of the metal are black, instead of red, as on copper. The following are a few solutions for producing patina on brass.

Brown.

Barium sulphide ..	1 oz.
Water	2 quarts.

Use the solution warm.

Architectural Bronze.

Potassium sulphide ..	1 oz.
Water	1 quart.

Immerse the metal in a hot solution, rinse in cold water, and tone off with a soft scratch brush before applying lacquer.

Bright Green.

Common Salt ..	..	4 oz.
Sal. Ammoniac..	..	4 oz.
Ammonia .880 ..	..	3 oz.
Vinegar ..	..	1 quart.

Cover the work with the solution, and allow to dry slowly. Dissolve some beeswax in turpentine, add a few drops of olive oil, and apply with a soft leather.

Pale Gold to Orange.

Copper carbonate	..	4 oz.
Caustic soda ..	..	2 oz.
Water	..	2 quarts.

Immerse in a hot solution. The time of the immersion, and the temperature of the liquid influences the shades. After rinsing and drying, use a pale gold lacquer.

IV. ELECTROLYTIC.

By this process metallic films, and films of oxides are deposited on the base metal by electrolytic action. Electro-plating is a familiar example of this method, but many other metals besides nickel and silver may be deposited from plating solutions. The process is outside the scope of ordinary metalwork practice, but it can be demonstrated experimentally in the school laboratory.

LACQUERING

Few metals will withstand exposure to the atmosphere without becoming tarnished, and their oxides, sulphides, etc., which form the films of colour on the surface are not permanent, being sooner or later affected by the corrosive gases in the air.

In order to preserve the colour, produced by any of the methods described, on a metallic surface, it is necessary to apply a thin coat of transparent material, the chief purpose of which is to prevent contact between the air and metal.

Liquids used for this purpose are called lacquers, and they may be bright or dull, coloured or transparent. They consist of volatile solvents such as alcohol, and amyl acetate (pear oil), in which gums and resins have been dissolved.

When applied to the work with a soft camel hair brush, the solvent evaporates, leaving the thin protective film. Care should be taken when buying lacquers to see that only the best are supplied. The cheaper qualities made from resin and benzine are worthless, and ruin the appearance of good work.

Lacquer may be applied to either hot or cold surfaces, but the hot process produces a film which is very hard, and not easily scratched.

The work should be placed on a hot plate over a gas stove or ring, until it attains such a temperature that it can be comfortably handled; the liquid is then applied with a brush, whilst precautions are taken to avoid the formation of "runs" or air bubbles. If the lacquer should show signs of cloudiness when on the metal, replace the work on the hot plate for a few seconds, then regulate the heat, and allow to harden off at a temperature of about 100° Fah.

BOOKS FOR REFERENCE.

"Colouring of Metals"; Field and Bonney, Messrs. Chapman and Hall.

INDEX.

TABLES.

LIST OF ILLUSTRATIONS.

APPENDIX.

Regulations, Syllabuses, and Examination Papers of the following Examining Bodies in Handicraft.

I. City and Guilds of London Institute.

II. Educational Handwork Association Examinations Board

CITY AND GUILDS OF LONDON INSTITUTE.

(INCORPORATED BY ROYAL CHARTER).

Extract from Regulations and Syllabuses for Examinations for Teachers of Handicraft.

TEACHERS' CERTIFICATES IN HANDICRAFT.

IN connection with the following scheme of examinations it is desired to direct the attention of Local Education Authorities to the Board of Education's Circular 1389 of 1927 and Administrative Memorandum No. 111 issued by the Board in January, 1934, to Local Education Authorities in England and Wales. In accordance with the practice under the terms of the above-mentioned Circular as applying to the Institute's Handicraft Examinations prior to 1935, the Board of Education will continue to regard a person who has passed the Second Handicraft Examination under the following syllabuses as qualified, so far as examination requirements are concerned, for recognition as a Teacher of Handicraft under Schedule I. 3 (*b*) of the Code, and as qualified for recognition as an Uncertificated Teacher; such a Candidate, therefore, when recognised, may, if the Local Education Authority so desires, act as an Uncertificated Teacher in Public Elementary Schools of subjects other than Handicraft.

The Board of Education will also as from August 1st, 1935, continue their practice of recognising temporarily as a Handicraft Teacher a candidate over eighteen years of age who has passed both Parts of the First Examination under the following syllabuses and who also fulfils certain other conditions ; a candidate so recognised may be employed by a Local Education Authority as a Handicraft Teacher at a salary which may take into account his previous skill and experience if he has been a skilled craftsman, and in other cases at a salary not in excess of the Uncertificated Teacher's salary scale.

As from August 1st, 1935, a person who has passed the Institute's First Handicraft Examination under the syllabuses in force in the years 1928 to 1934, inclusive, will not be eligible for temporary recognition as above described until he has also passed Group A of the Second Handicraft Examination in 1934 or prior thereto, or Part I. of the First Handicraft Examination under the following syllabuses in 1935 or subsequently thereto.

I. First Examination for Teachers of Handicraft.

The First Examination is divided into two Parts which may be taken in the same year or in separate years, and in the latter case in either order. A candidate who is over 17 years of age on March 15th preceding the date of the examination * is eligible to enter for either or both Parts.

The examination will comprise :—

Part I.

(*a*) *English.*—Two question papers, one of two hours' duration and one of two hours and a half.

(*b*) *Mathematics.*—Two question papers, one of two hours' duration and one of two hours and a half.

(*c*) *Elementary Science.*—A question paper of three hours' duration.

Exemptions.—A candidate who has passed a First Schools Examination or an equivalent examination*, with credit in English in either case, or the Matriculation Examination of any University recognised by the Universities Bureau of the British Empire, or who has been recognised as a Certificated Teacher, will be exempt from (*a*) English.

A Certificated Teacher who is certified by the Authorised Officer of a Local Education Authority to have passed in Mathematics and/or physical Science in his final examination for his Teacher's Certificate will also be exempt from (*b*) Mathematics and/or (*c*) Elementary Science.

A Graduate of a University recognised by the Universities Bureau of the British Empire will be exempt from (*a*) English, and if in either the Intermediate or Final Examination for his degree he passed in Mathematics and/or physical Science, from (*b*) Mathematics and/or (*c*) Elementary Science.

* See Regulations.

PART II.

(*d*) *Drawing.*—A question paper in relation to Woodwork, or, alternatively, a question paper in relation to Metalwork, in each case of three hours' duration.

(*e*) *Tools and Materials used in Handicraft.*—A question paper in relation to Woodwork, or, alternatively, a question paper in relation to Metalwork, in each case of three hours' duration and requiring answers in writing or by sketches.

(*f*) *Practical Tests.*—A test paper will be set in Woodwork, or, alternatively, in Metalwork, in each case of four hours' duration.

II. SECOND EXAMINATION FOR TEACHERS OF HANDICRAFT.

A candidate over 19 years of age on March 15th preceding the date of the examination who either has passed the First Handicraft Examination under the present syllabus, or is otherwise qualified as mentioned above, and has in each case had not less than six months of full-time teaching in a recognised day school or its equivalent, will be eligible to enter for the Second Handicraft Examination.

The examination will comprise :—

(*g*) *Drawing.*—Two question papers in relation to Woodwork, or, alternatively, two question papers in relation to Metalwork ; in each case each paper will be of three hours' duration.

(*h*) *Technology of Woodwork and Metalwork.*—A question paper on the Technology of Woodwork with questions on Metalwork of a character less advanced than those on Woodwork, or, alternatively, a question paper on the Technology of Metalwork with questions on Woodwork of a character less advanced than those on Metalwork, in each case of three hours' duration and requiring answers in writing or by sketches.

In the former question paper each Woodworking candidate will be expected to answer two of the Metalwork questions satisfactorily, and in the latter paper each Metalworking candidate will be expected to answer two of the Woodwork questions satisfactorily.

(*j*) *Practical Tests.*—Two test papers in Woodwork, or, alternatively, two test papers in Metalwork ; in each case each test paper will be of four hours' duration.

(*k*) *Principles of Teaching.*—A question paper of three hours' duration, to be answered in writing.

SYLLABUSES.

FIRST EXAMINATION FOR TEACHERS OF HANDICRAFT.

PART II.

DRAWING.

NOTE.—Throughout the syllabus emphasis is laid upon the types of geometrical problems likely to be of use in workshop drawing and setting-out, and, as far as possible in the examination, examples will be set which are closely related to actual workshop practice.

In Relation to Metalwork.

(*a*) *Plane Geometry.*—The construction of the commoner rectilinear figures, including regular polygons, from various data. Symmetry and the method of working from centre lines.

Proportion : the use of parallels in the subdivision of lines. The construction of simple scales likely to be of use in workshop drawing.

The construction of circles from various data, including circles touching lines and circles touching circles.

Simple methods of constructing an ellipse, given the lengths of the main axes.

(*b*) *Solid Geometry.*—The construction of plans, elevations and sections of rectilinear and cylindrical solids projected in their correct relative positions on planes parallel to the main axes of the objects.

Developments based upon the prism, cylinder, pyramid and cone, or parts thereof.

Methods of projection must be according to the British Standards Institution Specification No. 308—1927, Engineering Drawing Office Practice.

(*c*) The construction of conventional isometric and oblique projections of simple rectilinear objects.

(*d*) The freehand sketching in outline of objects suitable to be made in metal by young pupils, with special reference to fitness for purpose and good proportion. The conventional methods of representation and the hand sketching of such details as nuts, bolt heads, rivets, screw threads and simple fastenings.

(*e*) The application of the foregoing to the making of working drawings, with special reference to the constructional details of the types of objects mentioned in the syllabus for the Practical Tests for the First Handicraft Examination.

Written Paper on Tools and Materials Used.

Note.—Candidates will be expected to make full use of hand sketches to illustrate their answers, and must have the power to use this method of illustration freely and effectively in view of its value in teaching.

For Metalwork.

The common tools and methods of procedure employed in working such exercises as may be set in the Practical Tests for the First Handicraft Examination. The care and maintenance of such tools, including safe methods of handling.

The characteristic properties and uses of the commoner metals and alloys. Solders.

The shop processes commonly employed in simple metalwork, including raising, hollowing and elementary decorative work.

The use of the drilling machine.

Practical Tests.

In Relation to Metalwork.

Exercises will be set in the working of the following metals --cast and wrought iron, mild and tool steel, brass, copper, aluminium, tin plate and lead.

No machine tools, other than drilling machines, may be used at the examination, but exercises will be set to test the candidate's ability to use the commoner metal working tools, including :—

Chisels—flat and cross-cut; files—various forms; drills; stocks--dies and taps; hack saw and snips; soldering bit and fluxes; simple forge tools.

The processes will include—

(i.) Simple forging (bending, twisting, drawing down, flattening, upsetting or jumping up);

(ii.) Hardening and tempering;

(iii.) Hand threading and tapping;

(iv.) Simple sheet metalwork (bending, seaming, and the wiring of straight and curved edges using hand methods only); simple raising and hollowing of copper sheet (or other similar metal); soldering and brazing; riveting; annealing.

SECOND EXAMINATION FOR TEACHERS OF HANDICRAFT.

Drawing.

The examination will consist of two question papers, each of three hours' duration.

In Relation to Metalwork.

Note.—Throughout the syllabus emphasis is laid upon the types of problems likely to be of use in workshop drawing and setting-out, and as far as possible in the examination examples will be set which are closely related to actual practice. Emphasis is also laid on the importance and value of hand sketching of simple machine apparatus, tools and other details found in the ordinary workshop equipment.

(*a*) *Plane Geometry.*—More advanced questions on the subjects specified in the syllabus for the First Handicraft Examination together with the following :—

Construction of diagonal scales—methods of enlargement and reduction of rectilinear figures in given proportions.

(*b*) *Solid Geometry.*—More difficult work than that specified for the First Handicraft Examination together with the construction of plans, elevations and sections projected on planes which are inclined to *two only* of the main axes of the object—*i.e.*, inclined but not oblique planes.

The determination of true lengths of lines and of the magnitudes of angles, from plans and elevations of objects of pyramidal form, in so far as such data may be necessary for the construction of such objects in metal. Projections of hexagonal bolt heads, also large screws with " V " or square threads, the helical curves to be accurately projected, and simple intersections and penetrations of geometrical solids such as prism, cylinder and cone, together with the development of their surfaces.

Methods of projection must be according to the British Standards Institution Specification No. 308—1927, Engineering Drawing Office Practice.

(*c*) The construction of such simple conventional isometric and oblique projections as may be useful in teaching pupils up to the age of 16 years.

(*d*) The designing and freehand sketching of objects suitable to be made in metal by pupils up to the age of 16 years, with special reference to fitness for purpose, good proportion, and the appropriate and restrained use of decoration. The freehand sketching of details of decorative processes, including those mentioned in the syllabus for the Practical Tests for the Second Handicraft Examination.

(*e*) The application of the foregoing to the making of working drawings, with special reference to the types of objects referred to in the syllabus for the Practical Tests for the Second Handicraft Examination.

(*f*) The making of drawings of simple workshop machines, apparatus and tools.

Written Paper on the Technology of Woodwork and Metalwork.

In Relation to Metalwork.

The application of the chief mechanical principles underlying the construction and manipulation of tools.

Machine tools, as used in the work referred to in the syllabus for the Practical Tests in the Second Handicraft Examination, including the construction and use of the lathe.

Types of lathe suitable for the school metalwork shop.

The equipment of the school metalwork shop for general schemes of work and also the classroom for the lighter forms of metalwork.

Power installations—steam engines, gas engines and electric motors ; the arrangement of shafting, pulleys and belts ; speeds required for different machines.

Lubricants and cutting compounds.

An outline of the methods of production of iron, steel (mild and tool), copper, lead, zinc, tin, and the common alloys.

Schemes of work suitable for boys up to the age of 16 years taken in (*a*) a fully equipped metalwork shop ; (*b*) a classroom with the commoner hand tools.

In Relation to both Woodwork and Metalwork.

Questions may be set on the special technique of Handicraft teaching, on notes of lessons on Woodwork or Metalwork and preparation of models, and on the arrangement of lessons and sequences of work, including the introduction of tools and instruction in constructional joints at particular periods of a boys' school life.

Practical Tests.

In Relation to Metalwork.

In addition to the tests specified for the First Handicraft Examination more difficult exercises will be set which involve the principal operations of bending, soldering, brazing, riveting, forging and single-handed welding.

The use of the lathe in turning, boring and screw cutting.

Sheet metalworking—the use of hand tools for seaming, wiring, raising, hollowing and embossing.

EXAMINATION PAPERS.

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HANDICRAFT EXAMINATIONS.

FIRST HANDICRAFT EXAMINATION—PART II. (METALWORK).

METALWORK DRAWING TEST.

The drawings are to be neatly finished in pencil, superfluous lines being rubbed out except where they form part of a geometrical construction, in which case they must show clearly but faintly.

The candidate is expected to use his own judgment regarding any dimensions or other details not clearly indicated on the attached figures.

Answer Questions 1, 2 *and* 3, *and any two other questions, i.e.,* FIVE *questions in all.*

Reference must be made to the attached plate for the Figures referred to in the questions. The dimensions on the drawings are in inches.

1. Draw the conventional views of a 3-in. × ½-in. hexagon headed nut and bolt when assembled.

2. Arrange and letter within a rectangle, 4¾-in. × 1½-in., the following :—

   " Details of fitment for cabinet—to be made in brass—scale twice full size."

3. Figure 1 shows the essentials of a small lathe carrier. Make a workshop drawing (plan and two elevations) showing all details and dimensions. The drawing should be arranged according to the recommendations of the British Standards Institution.

4. An isosceles triangle (base 2¾-in., slant side 4-in.), with a long side horizontal, represents the elevation of a right circular cone. It is cut by a horizontal plane passing through the centre of its base.

   Draw the development of the portion of the cone below the section plane, assuming that it is to be but joined along the line at which the cone touches the horizontal plane.

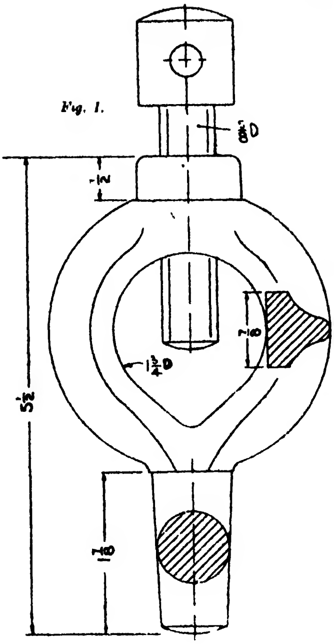
5. Make *either* an oblique projection *or* a conventional isometric projection (with one end as the nearest face) of the V-block shown in Fig. 2.

   The radii at the internal angles may be omitted and the corners left sharp.

6. A horizontal plane, containing a regular pentagon of 2-in. side, and its circumscribing circle is turned about an axis through the centre of the pentagon and one of its corners until the orthographic projection of the circumscribing circle becomes an ellipse with minor axis 2-in. Draw the plan of the pentagon and its circumscribing circle in the new position.

7. Carefully set out the details of a ¾-in. British Standard spanner to the dimensions shown in Fig. 3. The drawing should be as accurate as possible and should show clearly the construction made for positioning the centres of the various arcs of circles drawn. The nut about which the spanner is drawn should be set out first by using the 1½ D. and ⅛-in. rule.

Fig. 1.



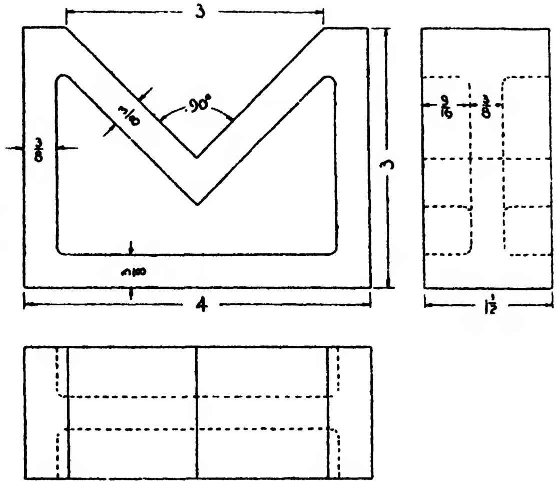
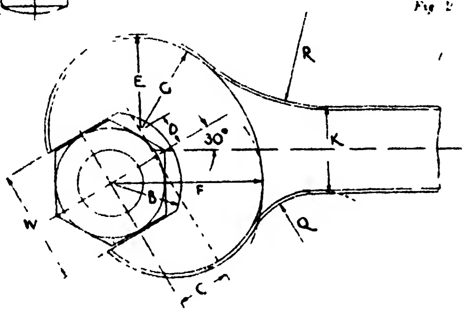


Fig. 2



B	C	D	E	F
785	611	326	1 098	1 736
G	K	Q	R	W
1 043	974	816	2 336	1 305

Written Paper on Tools and Materials used for Metalwork.

Five *questions to be attempted.*

1. What do you consider to be the essential points to bear in mind when soldering with a " bit " ?

Write simple notes on (i.) a " burnt " iron, (ii.) soldering zinc sheet as distinct from tinplate, (iii.) " killed " spirits, (iv.) cleaning the work after soldering.

2. What points about a forge fire and forging should be borne in mind, if clean, crisp work is to be secured ?

Give brief reasons for (i.) a black spot appearing in an otherwise bright forge fire, (ii.) limiting the air supply, (iii.) the cracking of the metal at the tip when being drawn down from a square cross section to a round point, (iv.) a fire burning sideways in one direction.

3. Describe in detail the processes involved in silver soldering a side seam in a truncated cone of the following dimensions made of copper :—Top diameter 1-in., bottom diameter 2-ins., vertical height 2-ins.

4. Show, by means of sketches :—

(i.) A method of tightening a hacksaw blade.

(ii.) The clamp holding the scriber to the post of a scribing block.

(iii.) The fixings of a leg vice to a bench.

5. A boy, referring to a book in the workshop library, asks for an explanation of the following extracts. Indicate full replies :—

(i.) " A No. 4 B.A. die."

(ii.) " The tapping drill of $\frac{5}{16}$-in. Whitworth screw is $\frac{1}{4}$-in."

(iii.) " Use a bottoming tap for a blind hole."

(iv.) " A tapping drill for cast iron should be on the big side."

(v.) " A choked die will strip a thread."

6. Mention any particular action or precautions necessary for successfully working the following metals :—(i.) Cast iron, (ii.) tool steel, (iii.) sheet zinc, (iv.) sheet copper, (v.) tinned plate.

7. What are the characteristics of (*a*) good forgework, and (*b*) good decorative copper work ?

What finishes (temporary or permanent) are available for preserving the work in each case ?

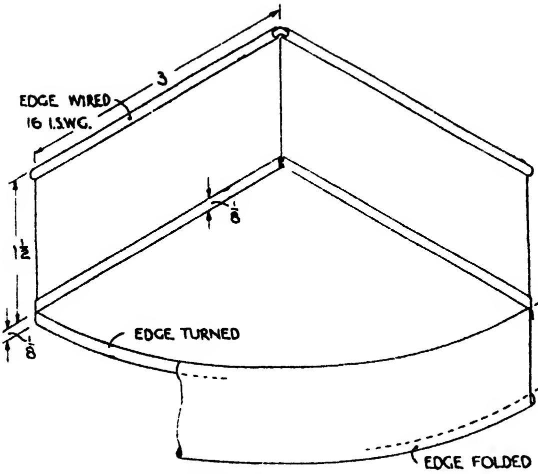


FIG. 1.

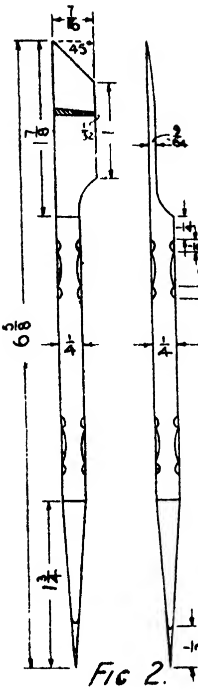


FIG 2.

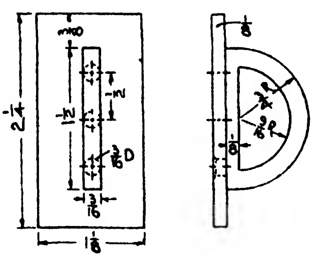


FIG. 3.

PRACTICAL TEST IN METALWORKING.

All three tests, which are of equal mark value, should be attempted, and one quite completed.

1. *Tinwork* (*Fig.* 1)—

This exercise is to be made from three pieces of tinplate, as follows :—

(i.) A quadrant with edges turned up at right angles, *i.e.*, two straight edges in one direction, and one curved edge in the opposite direction.

(ii.) A strip, with folded edge, bent to the form of a quarter of a circle, and lap jointed and soft soldered to the curved edge of the quadrant.

(iii.) A strip, with a wired edge, bent to a right angle, and lap jointed and soft soldered to the two straight edges of the quadrant on the side away from the curved strip.

2. *Forgework* (*Fig.* 2)—

Make the steel striking knife. Harden, temper and finish it bright all over. Sharpen it. The temper colours need not be left, but the job should be well greased with vaseline.

3. *Fitting* (*Fig.* 3)—

In this the fitting of the three pins should be complete and carefully done. The semi-circular outline need not be finished, but the surplus metal should be removed systematically. The pieces should be prepared for riveting but MUST NOT BE RIVETED.

SECOND HANDICRAFT EXAMINATION (METALWORK).

Metalwork Drawing Test—First Paper.

The drawings are to be neatly finished in pencil, superfluous lines being rubbed out except where they form part of a geometrical construction, in which case they must show clearly but faintly.

The candidate is expected to use his own judgment regarding any dimensions or other details not clearly indicated on the attached figures.

Not more than Four *questions to be attempted.*

Reference must be made to the attached plate for the figures referred to in the question. Dimensions on the drawings are in inches.

1. Develop the surface of the conical frustum in Fig. 1 and measure the length of the longer curved edge of the development.

2. A piece of sheet metal is brought to the form shown in Fig. 2 by scoring a vee-shaped groove almost through its thickness and then folding so as to close the vee-cut. What is the theoretical angle of the vee for the conditions in Fig. 2?

3. Draw 1½ times full size the plan of the ratchet wheel in Fig. 3 when it lies on a plane inclined at 30° to the horizontal (Thickness ¼-in.).

4. Indicate by sketches the main features of a back-geared screw-cutting lathe and letter-in the names of its principal parts.

5. Make an oblique projection of the ratchet wheel in Question 3.

6. A bar is turned to the shape shown in Figure 4. Two flats are then symmetrically milled on opposite sides of the part A until it is 1¼-in. thick, and the end B is machined to a square taper of 1 in 12 (½-in. × ½-in. at the small end). Draw a complete plan and elevation of the finished job.

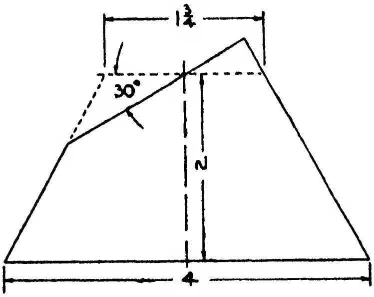


Fig 1

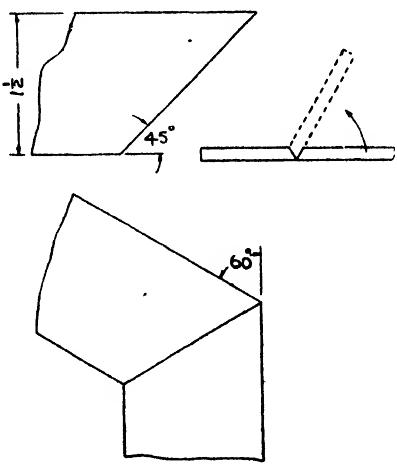


Fig 2

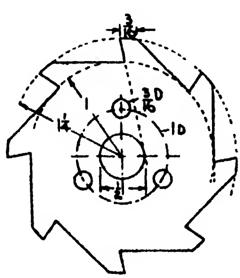


Fig 3

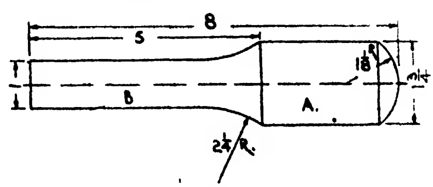


Fig 4

METALWORK DRAWING TEST—SECOND PAPER.

The drawings are to be neatly finished in pencil, superfluous lines being rubbed out except where they form part of a geometrical construction, in which case they must show clearly but faintly.

The candidate is expected to use his own judgment regarding any dimensions or other details not clearly indicated on the attached figures.

All the questions should be attempted.

Reference must be made to the attached plate for the Figures referred to in the questions. The dimensions on Fig. 1 are in inches.

1. Make a workshop drawing of the tin plate box, the shape (semi-elliptical elevation) and general dimensions of which are given in Fig. 1.

Indicate clearly the details of the joints and hinges and the treatment of the edges. Add a foot or feet to prevent rocking.

2. The essential details of a latch handle are shown in Fig. 2. Make a workshop drawing of such a handle which you feel would be successful with boys taking advanced metalwork. The construction, shaping, decoration and dimensions are left to the candidate, but the drawing should be arranged according to the recommendations of the British Standards Institution.

Do not copy the shape of the handle in Fig. 2, which is intended to suggest essentials only.

3. Using a rectangle of your paper 12-ins. × 9-ins., show by means of freehand sketches the details and construction of an object that you consider suitable as an individual job for a boy taking advanced metalwork. All the preliminary sketching necessary for arriving at your final suggestion should be made within the space allotted. The piece chosen may be either of mechanical, scientific or artistic interest.

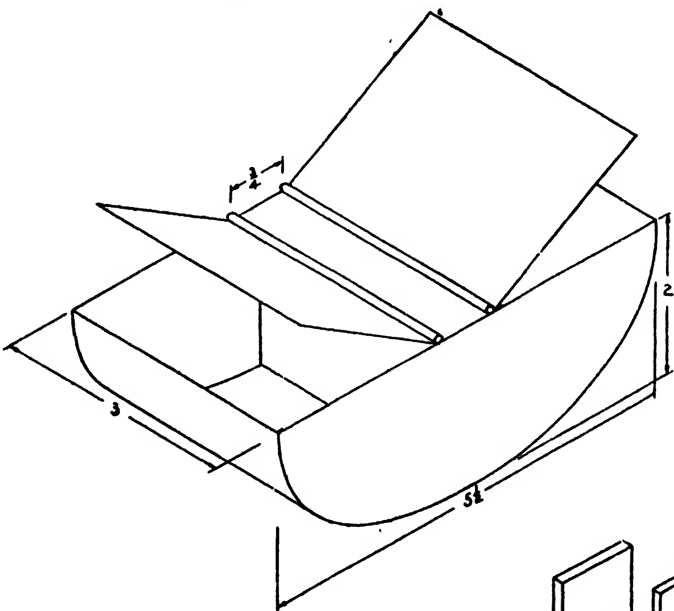


Fig. 1

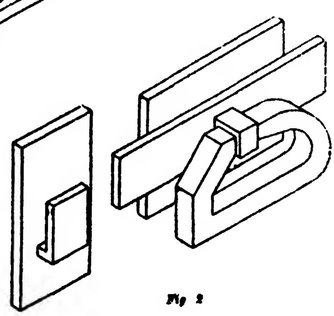


Fig 2

THE TECHNOLOGY OF METALWORK AND WOODWORK

(Paper for Metalwork Candidates).

Answer Six questions, FOUR *from Section A and* TWO *from Section B.*

Your answers should be freely illustrated by sketches.

A maximum of 20 *marks is allotted to each of the questions in Section* A *and of* 10 *marks to each of the questions in Section B.*

SECTION A.

Not more than FOUR *questions to be attempted from this Section.*

1. What educational merits can be claimed for machine tools in a school workshop?

What benefits, if any, does a boy derive from the experience of cutting a screw thread in a lathe instead of with dies?

2. Explain how your knowledge of oxidation and combustion affects your working (i.) at the forge, (ii.) with a blowpipe, (iii.) at a soldering stove.

3. Describe the operations of "hollowing" and "raising," the tools generally employed, and the treatment of the metal at various stages of the work, assuming that the metal is copper.

4. Some 60 brass keys (details in Fig. 1) for bookbinding sewing frames are required in the practical workroom of a school. How would you organise the repetition work of making them so as to interfere as little as possible with your general course work, but in a way which would be valuable as an illustration of method in production?

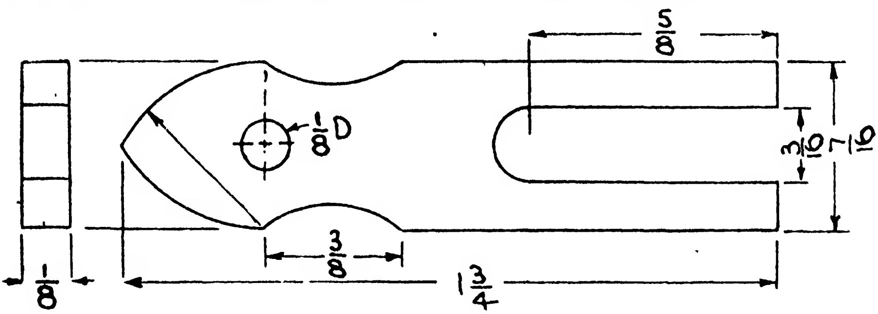


Fig. 1.

5. What would you have to say to boys about alloys—brass in particular? State the age of the boys you have in mind.

6. Outline the arrangements by which the power generated by an electric motor is transmitted through a mainshaft to different machines in a workshop. Make sketches explanatory of a countershaft and striking gear through which a single machine may be controlled.

7. Give a few notes on, and a series of sketches illustrating, jobs for the lathe *or* for the forge *or* in copper, to form a short, preliminary course, covering essential tool operations and basic constructions.

SECTION B.

Not more than TWO *questions to be attempted from this Section.*

8. Sketch, about twice full-size, a section across the mouth of a jack plane, indicating clearly the position of the cutting and cap irons, and the angles at which the cutting iron is ground and sharpened. Describe how the plane is adjusted for various depths of cut, and how the cutting edge is maintained in good order

9. Show by sketches and notes the constructive details of a shallow tray intended for the storage of small bolts and nuts. The tray is to be approximately 16-ins. long, 12-ins. wide, and 1½-ins. deep, with partitions as you think fit.

It is to be understood that something better than nailed butt joints would be used in its construction.

Specify the material that you would use in making such a tray.

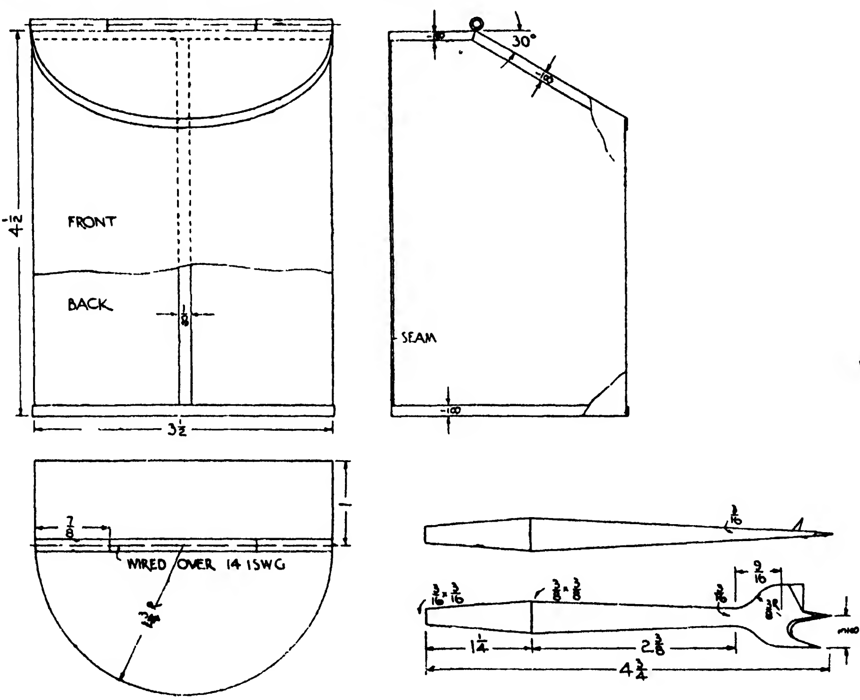
10. Describe exactly, with sketches, the methods that you would adopt when marking out and cutting the end of a block of wood, 3-ins. wide and ¾-in. thick, "square," *i e.*, at right angles to the other faces of the block, (*a*) for rough work where approximate accuracy is sufficient, and (*b*) for finer work where great accuracy and a good finish are needed.

Practical Test in Metalworking—First Paper.

Both tests should be attempted.

1. Make the tin canister shown. Soft solder all joints.

2. Make the ¾-in. centre bit shown. Harden and temper it ready for use. Wherever possible the work should be left from the hammer.



Practical Test in Metalworking—Second Paper.

Both tests should be attempted. The tests are of equal mark value.

1 *Sugar Bowl* (*Fig.* 1)—

Make the sugar bowl in gilding metal.

There is one joint in the sides and this, and the joint between the bottom and sides, re to be silver soldered. The bottom may be fitted or planted on.

The joint in the plinth should be silver soldered, but the plinth may be soft soldered on to the body.

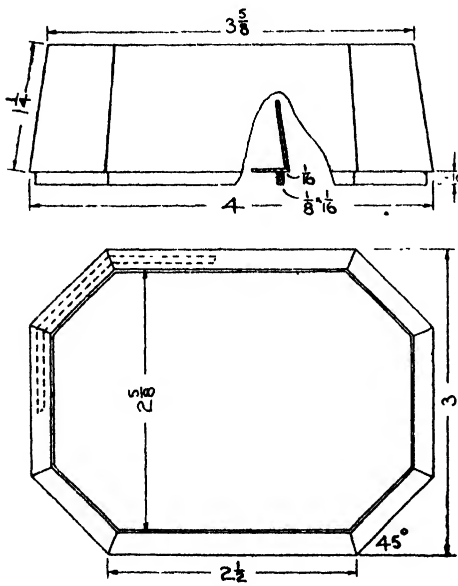
Either a smooth or a hammer finish may be left on the work, which should be polished and slightly greased.

2. *Cramp End* (*Fig.* 2).

Turn the piece B. Piece B may be sawn (instead of being parted off) and left rough.

Turn the end of the piece A, to suit the hole in piece B. Note that B is to revolve A.

Connect A and B with the set screw C. The end of screw C should be shouldered down with the file.



FIG·1

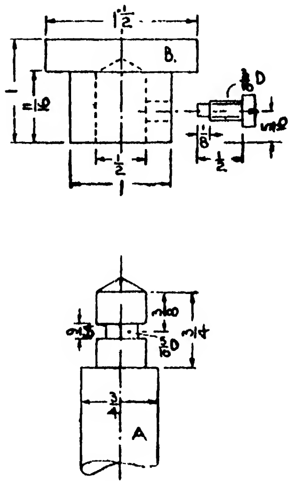


FIG. 2

FIRST HANDICRAFT EXAMINATION—PART II. (METALWORK).

DRAWING AND DESIGN IN RELATION TO METALWORK.

The drawings are to be neatly finished in pencil, superfluous lines being rubbed out except where they form part of a geometrical construction, in which case they must show clearly but faintly.

The candidate is expected to use his own judgment regarding any dimensions or other details not clearly indicated on the attached figures.

Not more than FOUR *questions to be attempted,* THREE *from Section A and* ONE *from Section B.*

Reference must be made to the attached plate for the Figures referred to in the questions. The dimensions on the drawings are in inches.

SECTION A.

THREE *questions only to be attempted from this section.*

1. The development of a cone is shown in Fig. 1. Draw the elevation of the lower part of the cone after the development has been cut along the straight line AB and bent to shape. A and B are equidistant from the apex.

2. Fig. 2 shows an elevation and part plan (regular octagon) of a metal jug, the thickness of the metal and the handle being omitted. Draw a new elevation of the jug, looking in the direction of the arrow. Suggest a form for the handle.

3. Fig. 3 gives details of part of a latch, the plan being incomplete. Complete the plan three times full size and set out the true shape of one of the sloping faces.

4. What is the scale of Fig. 4? Construct a scale by which the hook may be drawn $1\frac{1}{2}$ times full size. Set out the back plate only, to that scale, and fully dimension it.

SECTION B.

ONE *question only to be attempted from this section.*

5. Sketch three latches suitable for use on the following:—
   (i.) A low entrance gate to the front garden of a house
   (ii.) A side or back garden gate.
   (iii.) A door—*e.g.*, a pantry door inside the house.

Indicate the construction in each case and give reasons for the forms you suggest.

6. Make freehand sketches of a small garden rake that could be constructed or produced in a school workshop by—
   (i.) Riveting round points into the frame of the rake.
   (ii.) Twisting and bending the material of the frame so as to form the points.
   (iii.) Utilizing strip steel.

In each case show clearly the details of the connection between the metal part of the rake and the wood handle.

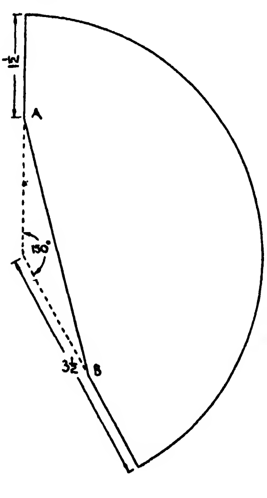


Fig 1

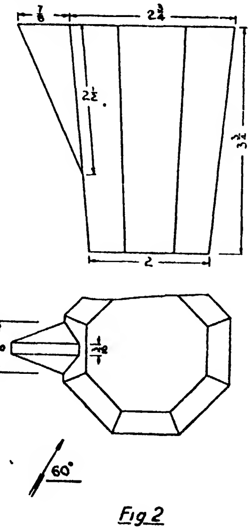


Fig 2

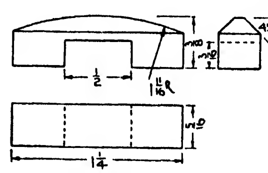


Fig 3

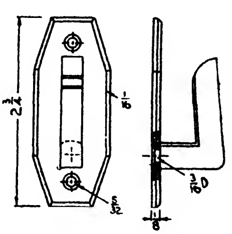


Fig 4

Written Paper on Tools and Materials used for Metalwork.

Five *questions to be attempted*

The maximum number of marks obtainable is the same for each question.

1. Distinguish between the applications of (i.) brazing, (ii.) soft soldering, (iii.) silver soldering. In each case, give an example where this method of joining would be preferable to the other two.

2. Contrast hot and cold bending, outlining precautions necessary in each case. Some metals are more difficult to deal with than others in cold bending and certain metals present greater or less difficulty according to the state they are in. Comment upon this.

3. Explain, with the aid of sketches, how you would ensure—

   (i.) Accuracy in direction of a hole drilled diametrically through a round bar.

   (ii.) Correct register between lines of holes in two plates being riveted together.

   (iii.) Uniform depth of a number of blind holes.

4. What difficulties would you expect to meet when producing, with hand tools, a flat face on a small rectangular block of cast iron? Assume that the block is 2 in. by 2 in. by 1 in. and is fresh from the foundry. Describe how you would proceed to face the block and test its flatness.

5. Show, by a sketch in each case, how you would connect:—

   (i.) A straight copper bit with its shank.

   (ii.) A hatchet copper bit with its shank.

   (iii.) The legs of a pair of spring dividers.

   (iv.) A drill chuck with the spindle of a drilling machine.

6. Write concise notes on tinplate as a material for use in a school metalwork shop.

7. Describe, under headings, how you would make a planished ring—as for the foot of a bowl—from copper strip $\frac{1}{4}$-in. by $\frac{1}{8}$-in. The outside diameter of the ring may be taken as $1\frac{3}{4}$ inches.

8. Make sketches and explain, as you would to the uninitiated, the probable cause of:—

   (i.) A pair of snips producing a burr when cutting tinplate.

   (ii.) A twist drill becoming "blued" in use.

   (iii.) Ineffective closing of a countersunk rivet.

Practical Test in Metalworking.

Use your own judgment to supply any dimensions or other details not clearly shown in the drawings.

Both Tests should be Attempted.

Reference must be made to the attached plate for the Figures mentioned in the questions. All the dimensions given on the drawings are in inches. The plate may be detached for easy reference.

1. From the tinplate provided, make the tray shown in Figure 1. Use your judgment to decide where the job should be soft soldered.

Carefully avoid damage to the material when stamping it with your number.

2. Make the brass bolt shown in Figure 2.

The sharp bend at the end of the front plate is to be scored, folded and silver soldered. The thumb piece is to be riveted, sliding tight, to the bolt.

The work should be stamped with your number on the back of the bolt piece before facing and assembling. Importance will be attached to the care with which the stamping is done.

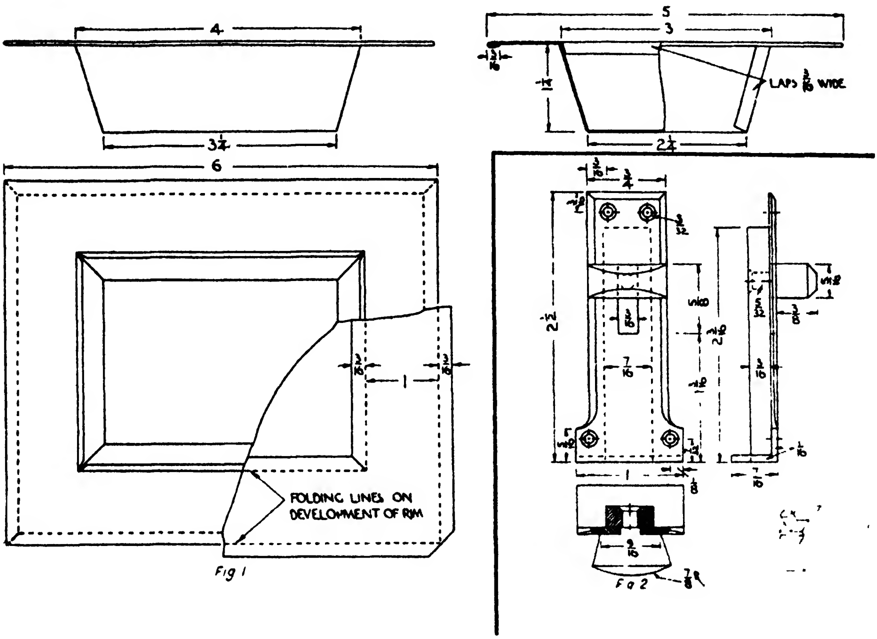


Fig 1

Fig 2

SECOND HANDICRAFT EXAMINATION (METALWORK).

Drawing and Design in Relation to Metalwork. First Paper.

The drawings are to be neatly finished in pencil, superfluous lines being rubbed out except where they form part of a geometrical construction, in which case they must show clearly but faintly.

The candidate is expected to use his own judgment regarding any dimensions or other details not clearly indicated on the attached figures.

Not more than Four *questions to be attempted*

The maximum number of marks obtainable is the same for each question.

Reference must be made to the attached plate for the Figures referred to in the questions. Dimensions on the drawings are in inches.

1. Fig. 1 shows an elevation and part plan (regular octagon) of a metal jug, the handle and the thickness of the metal omitted. Set out the development of the spout and the true shape of the face of the jug to which it is attached.

2. Assume that the jug (Fig. 1) is tipped over so that the face ABCD rests on a horizontal plane Project a new elevation on a vertical plane parallel to AB.

3. Make freehand sketches illustrating the construction of a forge and show clearly the mechanism used for producing the blast.

4. Make a conventional isometric drawing of the bottom fuller shown in Fig. 2.

5 The staple in Fig 3 is made from $\frac{1}{2}$ in. round stuff, the arms being filed to shape Complete, twice full size, the front elevation and carefully draw a sectional plan with the portion above the horizontal plane, represented by the line AB, removed.

6 Assume that floor space in a workshop 38 ft by 20 ft. is available with windows at one end and along the right-hand side looking from that end. Set out, to scale where possible, the arrangements of benches, equipment, etc., that you would make on the assumption that 16 boys are to be accommodated and general metalwork taught through a three-year course. Sketch the type of bench that you would recommend.

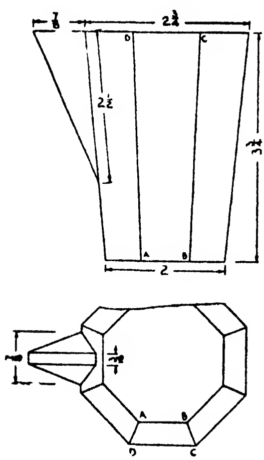


Fig 1

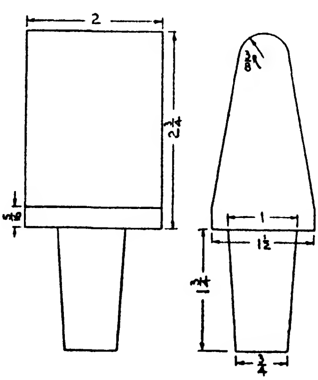


Fig 2

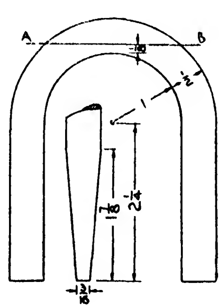


Fig 3

DRAWING AND DESIGN IN RELATION TO METALWORK. SECOND PAPER.

The drawings are to be neatly finished in pencil, superfluous lines being rubbed ont except where they form part of a geometrical construction, in which case they must show clearly but faintly.

A sheet of thin paper for rough work is provided and this must be attached to your sheet of finished drawings at the close of the examination.

TWO *questions only to be attempted.*

The work suggested in answer to the two questions that you choose should be within your own capacity to produce.

1. Sketch an electric light lantern or fitting suitable for the open porch of a house.

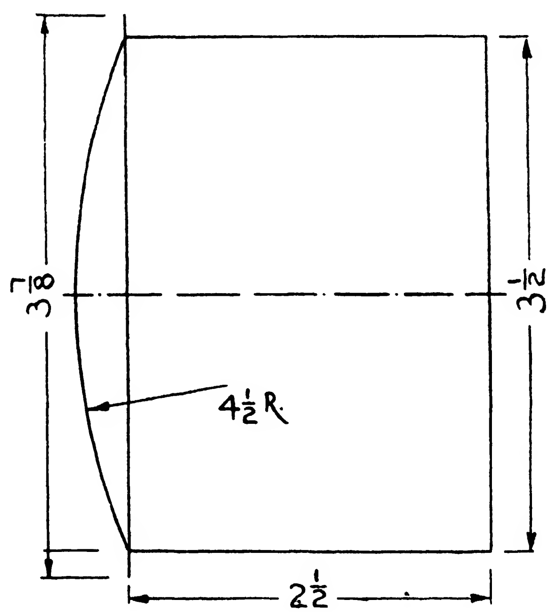
Your design should be modern in character and you may assume that either copper or stainless steel is to be used.

All the necessary details of construction should be set out in a working drawing—so far as possible full size.

The distance from the base of the lamp holder to the centre of the bulb may be taken as $4\frac{1}{2}$ in.; the diameter of the bulb as 3 in.

2. Details of the circular container of a clock movement are shown in the figure. Taking the octagonal prism as the basic form, design a metal clock case to receive the movement and container.

Make a sketch of your suggestion and a ful'y dimensioned working drawing showing the construction and details.



3. A certain cardboard container of 20 cigarettes measures 3 in. by $3\frac{3}{8}$ in by $\frac{5}{8}$ in. and a single cigarette $2\frac{7}{8}$ in. by $\frac{5}{16}$ in. diameter Design and show, in sketch form, a suggestion for a hinged metal box to hold approximately 100 cigarettes Indicate all details of construction and the principal dimensions.

THE TECHNOLOGY OF METALWORK AND WOODWORK.

(Paper for Metalwork Candidates).

Answer SIX *questions,* FOUR *from Section A and* TWO *from Section B.*

Your answers should be freely illustrated by sketches.

A maximum of 20 *marks is allotted to each of the questions in Section A and of* 10 *marks to each of the questions in Section B*

SECTION A.

Not more than FOUR *questions to be attempted from this Section.*

1. How does wear or want of adjustment on a lathe generally indicate its presence on the work and on the operation of the cutting tool?

Sketch the principal adjustments to take up wear that can usually be made between the rotating and/or sliding parts of a lathe.

2. Describe the troubles that may arise from a thoughtless use of an emery grinder

What precautions must be taken to ensure efficient working and a reasonable length of life for such a wheel?

3. Sketch three distinct methods of keeping work under control while it is hot.

Illustrate how you would prepare to braze two pieces of pipe together to form an elbow.

4. Write concise notes on the cutting action of (*a*) lathe tools, (*b*) taps and (*c*) cold chisels.

5. Assuming that you require a hollow brass casting—simple taper in form—for the column of an electric table lamp, describe how you would make the necessary pattern, etc. for it On receiving the casting from the foundry, what probable faults in the casting would you look for?

6. Illustrate—mainly by sketches—the stages in making and turning a brass ring $2\frac{1}{2}$-in. diameter, cross-section $\frac{1}{4}$-in. octagon, from $\frac{5}{16}$ square rod

7. Enumerate the fundamental points that it is necessary to stress from the earliest stages in the teaching of copper working and explain why it is necessary when annealing flat copper plate :—

(i.) To support it away from the hearth on small pieces of material.
(ii.) To keep the hearth free from soft solder.
(iii.) To scour and dry the metal thoroughly before working it.

8. Why are the faces of some pulleys curved while others are flat? Explain differences in their use.

What are the most frequent causes of belts coming off pulleys? Set out the points that should be clearly understood when replacing or changing a belt.

SECTION B.

Not more than TWO *questions to be attempted from this Section.*

9. Sketch and describe the undermentioned tools, and explain the circumstances in which each would be used :—

(*a*) A cutting gauge.
(*b*) A mortise gauge.
(*c*) A rebate plane.

10. Show, by means of sketches and notes, the constructional details of a small nest of drawers suitable for holding small tools and sundries in a metalwork room. You may assume that the article will be approximately 14-in. long, 10-in. high, and 10-in. deep; the arrangement of the drawers, etc., is left to your own judgment. State the material of which the article would be made.

11. Suppose that you are required to make a disc of pine wood, 18-in. diameter and $\frac{7}{8}$-in. thick. Assuming that the wood is already planed to thickness and that no lathe is available, explain with sketches how you would make the disc. Sketch the tools you would use for setting out and making the curved edge.

PRACTICAL TEST IN METALWORKING—FIRST PAPER.

Use your own judgment to supply any dimensions or other details not clearly shown on the drawings.

All dimensions on the drawings on the attached plate are in inches.

The plate may be detached for easy reference.

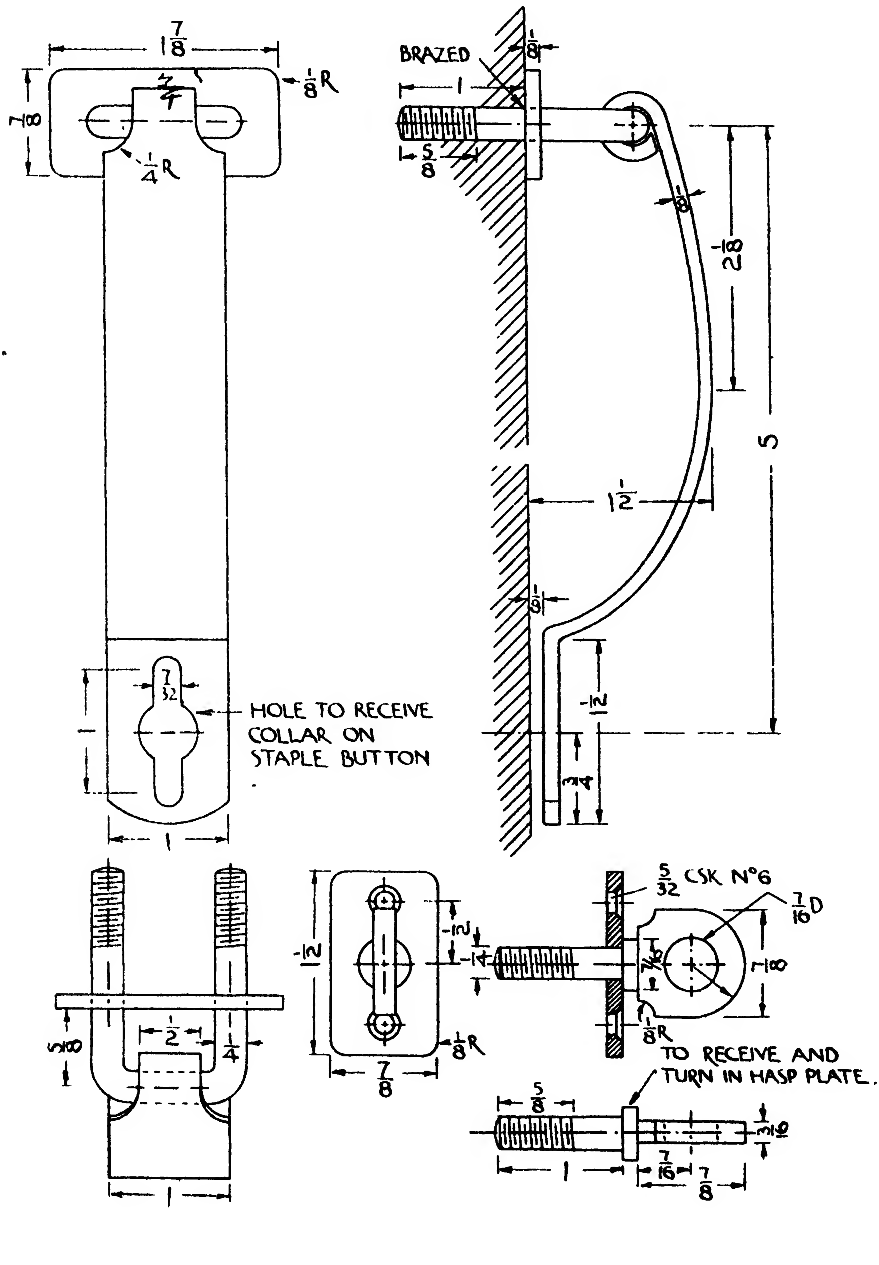
Make the hasp plate and button, the details of which are shown in the attached plate.

Note :

(i.) The threaded U piece is to be brazed to its backplate.

(ii.) The padlock staple is to turn in the hasp plate and act as a button when not padlocked. The collar on the padlock staple should be a rotating fit in the hole and of a thickness determined by the thickness of the hasp plate.

The work should be well finished and greased all over, and, if necessary, the parts tied together with a numbered label before being given up. Where possible, the parts should be stamped on the back with the candidate's number.



Practical Test in Metalworking—Second Paper.

Use your own judgment to supply any dimensions or other details not clearly shown in the drawings.

Both Tests should be attempted. *The tests are of equal mark value.*

All dimensions on the drawings on the attached plate are in inches.
The plate may be detached for easy reference.

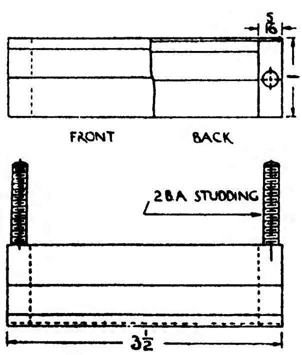
1. Make the brass drawer pull. All joints are to be silver-soldered.

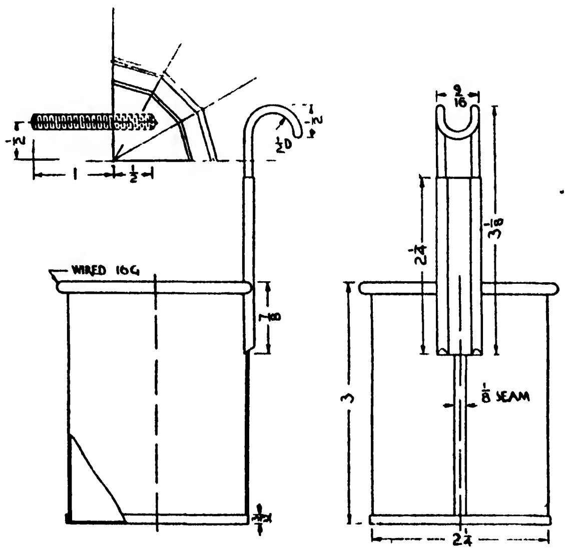
The work should be stamped with your examination number on the inside before finishing the outside. Credit will be lost on work spoiled by stamping.

2. Make the tinplate measure; soft-solder where necessary.

Carefully stamp your examination number on the outside of the bottom before soldering to the body.

(Third angle projection has been used in the drawing for convenience in arrangement).





EDUCATIONAL HANDWORK ASSOCIATION.

EXAMINATIONS BOARD.

METALWORK.

SPECIAL REGULATIONS AND SYLLABUS OF WORK.

The Examination consists of two stages, the First Year Examination and the Final Examination, for each of which a certificate is issued.

The Board of Education are prepared to regard as qualified under Schedule I. 3(*b*) of the Code Certificated Teachers who attend the First and Second Year Summer School Courses, each of four weeks' duration, conducted by the Association, and obtain the Certificate at the end of each Course.

CONDITIONS OF ENTRY FOR THE EXAMINATIONS.

To be qualified to sit for the Examination in either stage, the candidate must be certified as having completed an approved course covering the Syllabus outlined below.

No candidate may enter for the Final Examination unless he holds the Board's First Year Certificate in Metalwork, or Produces evidence of having passed the First Handicraft Examination (Metalwork) of the City and Guilds of London Institute within five years of entering for this examination.

A Certificated Teacher who follows a Course of Training in Special Handwork as a part of a Training College Course may apply to be exempted from the first four weeks' Course and Examination.

Candidates for the Final Examination are required to " satisfy the Board's Examiner " in the Pedagogics of Handwork (First Examination) as a condition of the award of a Certificate.

SYLLABUS OF WORK :—

FIRST YEAR EXAMINATION.

First Year Certificates in Metalwork will be granted for success in (*a*) an approved course of preparation, and (*b*) an examination, as outlined below.

Course Work.—The *Practical Work* of the Course should consist of the application of the metalworking processes named below to the making of articles devised by the candidate for some purpose related to the personal, home or school interests of pupils. These articles should be suitable to be included in a course of school metalwork with intelligent pupils up to 14 years of age.

The Course should include the following processes : The use of the commoner fitter's tools, such as chisels, files, drills, small taps and dies. Methods of joining metals by riveting, hard and soft soldering. Simple tinplate work. Elementary artistic metal-work ; piercing and raising. Forge work to the stage of bending, twisting and drawing-down.

Credit will be given not only for fine workmanship, but also for the extent to which sound construction, the appropriate use of material, fitness for purpose, good proportion and restraint in decoration have been considered in the design of the articles made during the Course.

The *Drawing* done in connection with the Practical Work must show a detail of construction, and may take the form of dimensioned sketches or accurate mechanical drawings. They should include the usual orthographic projections, and occasionally simple oblique or conventional isometric projections.

In addition to doing the above drawings, each candidate must submit the following sheets of drawings, duly certified by an officer of an E.H.A. Summer School or approved course, as being the unaided work of the candidate :—

1. On a half imperial sheet (22-in. × 15-in.) work out at least six problems in geometry, chosen from the following :—The construction of plane figures from given data ; circles touching circles and circles touching lines ; the construction of scales ; the geometrical setting-out of patterns suitable for decorating metal objects ; the orthographic projections of simple rectilinear solids and of the cone, including the development of their surfaces.

2. On a half imperial sheet make a perspective sketch and also an accurate mechanical drawing of a piece of mechanism such as would be found in an equipment for elementary metalwork, *e.g.*, parallel vice; breast drill, simple drilling machine, headstock and tailstock of lathe, compound slide rest.

Examination.

Theory—Written Paper—Three Hours.

The description, use and maintenance of the tools used in the simpler processes of metalwork. The materials used for school metalwork. The principles of construction underlying the design of common objects so far as they may be applied in school metalwork. The devising of exercises and the framing of schemes of work for pupils up to the age of 14 years.

Drawing—Three Hours.

The preparation of accurate working drawings of objects up to the standard of difficulty indicated in the Syllabus for the Practical Work of the Course, and also of simple details of machine construction. Exercises in simple plane geometry. The design and sketching of objects and decorative details suitable for application in elementary metalwork courses.

Practical Test—Four Hours.

The execution of pieces of work involving processes similar to those employed in the Course Work.

FINAL EXAMINATION.

Final Certificates in Metalwork will be granted for success in (*a*) an approved course of preparation, and (*b*) an examination, as outlined below.

Course Work—The *Practical Work* of the Course should be devised to make the candidate competent to undertake any piece of straightforward metalwork including the processes specified for the First Year Course, but to a more advanced stage of difficulty; and including also brazing; forge-work, including upsetting and simple welding; lathe-work with hand tools and with the compound slide rest, including simple screw cutting.

The merit of the work will be judged on principles similar to those governing the award of the First Year Certificate, but a much higher standard of technique will be required.

The *Drawing* done in connection with the Practical Work must show all details of construction, and may take the form of dimensioned sketches or accurate mechanical drawings. They should include the usual orthographic projections, and occasionally simple oblique or conventional isometric projections.

In addition to doing the above drawings, each candidate must submit the following sheets of drawings, duly certified by an officer of an E.H.A. Summer School or approved course as being the unaided work of the candidate :—

1. On a half imperial sheet work at least Four examples in plane geometry selected from the following :—The locus of a point; the construction of cycloids, involutes and spirals; the design of cams.

2. On a half imperial sheet (22-ins. × 15-ins.) work at least Four examples in solid geometry selected from the following :—The intersection of pairs of regular solids, such as two cylinders of different diameters; a cylinder with a prism, pyramid or cone; a sphere with a prism, cylinder, pyramid or cone; the true projections of helical curves applied to screw threads.

Examination.

Theory—Written Paper—Three Hours.

The subject-matter of the Theory Syllabus for the First Year Certificate, but involving a wider and more thorough technical knowledge, together with the following : The preparation of schemes of work suitable for Senior Modern Schools, Central Schools and Secondary Schools. The methods, organisation and routine adopted in teaching metalwork to young pupils. The relation of craft teaching to the work in other school subjects.

Drawing—Three Hours.

As for the First Year Examination, but to a more advanced stage, and including exercises in solid geometry.

Practical Test—Six Hours.

The execution of pieces of work involving processes similar to those employed in the Course Work.

The following books will be found to cover much of the subject-matter of the Syllabuses :—

METALWORK FOR SCHOOLS AND COLLEGES by Armytage (Oxford University Press).
ELEMENTARY CRAFTWORK IN METAL by Shirley (B. T. Batsford).
A FIRST BOOK OF METALWORK by Cuzner (Dryad Press).
METALWORK by Adam and Evans (Edward Arnold).
MACHINE SHOP PRACTICE, Book I., by H. A. Jones (B. T. Batsford).
PRACTICAL INSTRUCTION IN THE SENIOR SCHOOL by Turner (Pitman).
HANDICRAFT IN THE SENIOR SCHOOL by White and Watson (University of London Press).
ENGINEERING WORKSHOP DRAWING by Parkinson (Pitman).
GEOMETRICAL DRAWING by Hanby (Pitman).

STEWART TAYLOR,
Secretary.

FIRST YEAR EXAMINATION 1934.

THEORY.

Time allowed—Three Hours.

Answer Question 1 *and four others.*

1. Some auxiliary metalwork is to be introduced in a workshop fully equipped for woodwork. Give details of suitable equipment and its layout. State briefly the type of work you would include in such a course of metalwork.

2. In what ways may material be ruined or work spoilt at forge work? Give in each case the correct procedure.

3. What instructions would you give your pupils on using a hacksaw and on the correct choice of blades for different materials and sections? Illustrate your answer.

4. Give in detail, the method you would adopt for keeping tools and equipment in good condition.

5. Make neat sketches of the more common types of hammers used in a metalwork shop. Name them and indicate the special uses for which they have been designed.

6. Four pairs of operations are given. Explain them in pairs showing the similarity or contrast as the case may be :—

(*a*) Filing, draw filing.
(*b*) Drilling, reaming.
(*c*) Drawing down, upsetting.
(*d*) Annealing, hardening.

THREE only to be answered.

PRACTICAL.

Time allowed—Four Hours.

Both tests to be attempted.

1. WINDOW CATCH.

The handle, of $\frac{1}{2}$-in. × $\frac{1}{4}$-in. mild steel, is to be forged at one end to the given sizes and shape and bent to a radius of $7\frac{1}{2}$-in., but it must not be filed except at the plate end to give a slight up and down movement between the two pieces.

The plate should be given an accurate file finish.

Rivet both pieces together to give a free movement and then file the $\frac{3}{16}$-in. × $\frac{3}{16}$-in. notches.

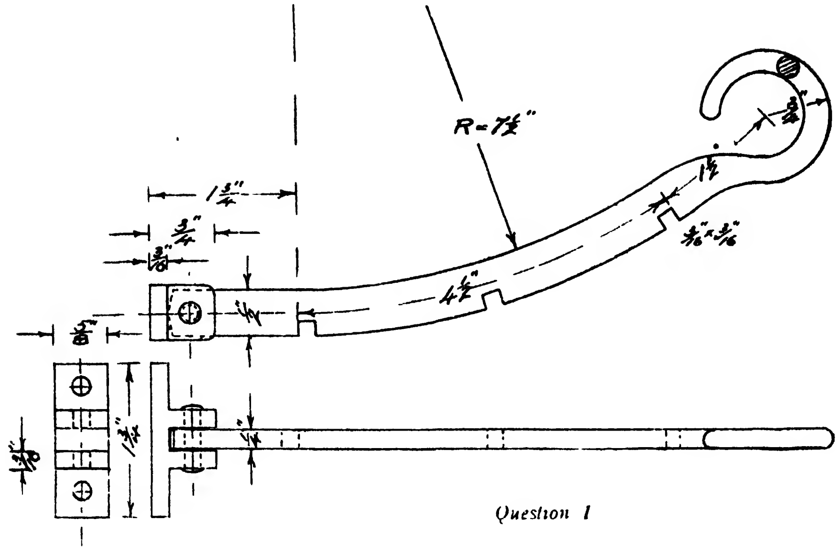
2. TRAY.

The sides slope outwards but the ends are upright.

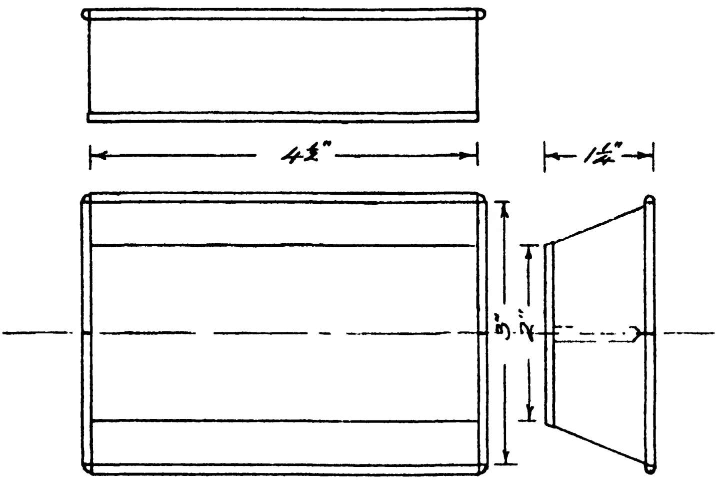
Make the sides and ends of two pieces of the same shape, the joints (plain lap) being at the centres of the ends as shown.

The bottom has a turned up edge all round.

Solder neatly and finally wire the top edge.



Question 1



Question 2

DRAWING

Time allowed—Three Hours.

Answer Question 1 *and two others.*

1. Drilling Machine Table.

Draw both projections given complete and add a front and a back elevation.

2. Draw two side elevations and a plan showing the hexagonal head of a ⅜-in. set screw of 16 threads per inch. The screw to be used for fixing the table, question 1, to the upright post. Show threads, etc., in the usual conventional way. Scale 4 times full size.

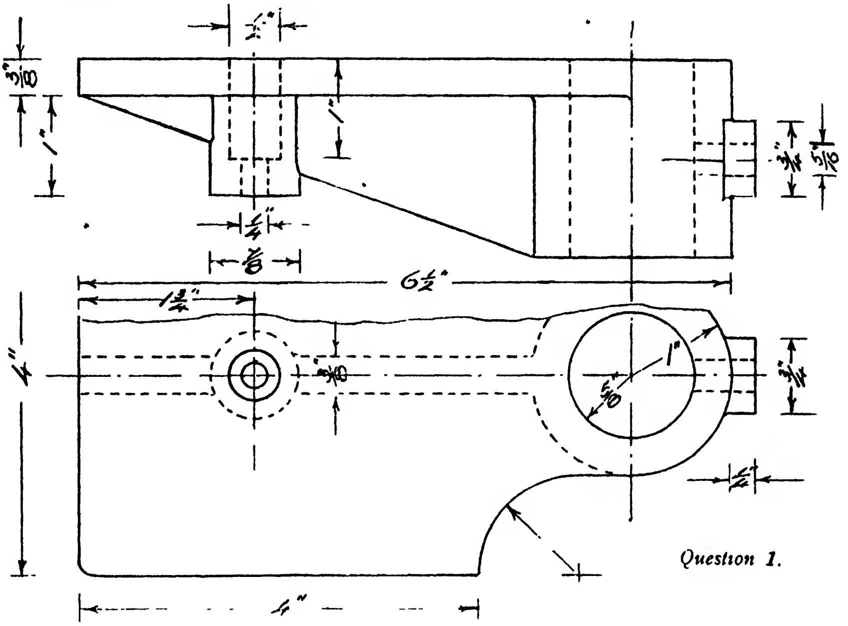
3. The top portion of a square wooden post is given in plan and elevations. The sloping surfaces shown in plan—(that is, the "roofs" of the post)—are to be covered with thin sheet metal.

Draw the development of the piece of metal which will cover half of it, the joint being along either of the centre lines.

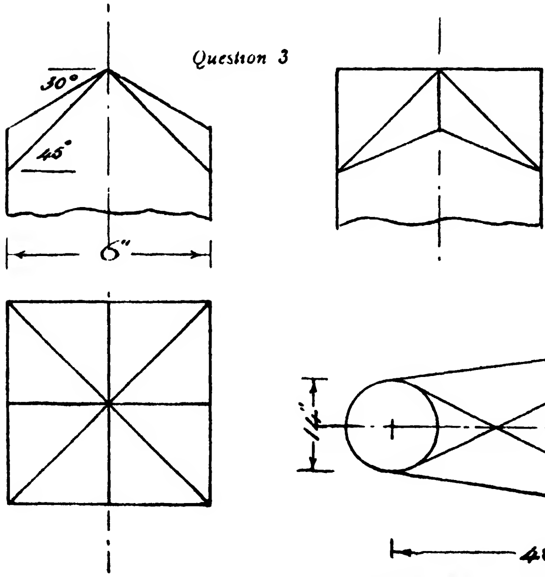
4. The figure represents, diagrammatically, pulleys joined with open and with crossed belts.

(*a*) Draw the figure accurately and showing clearly the construction to ⅛th scale.

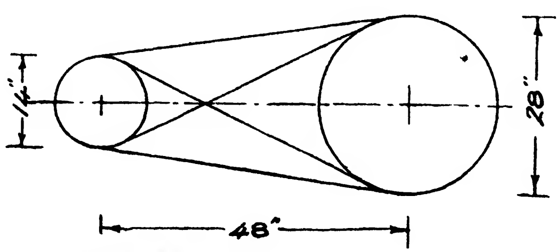
(*b*) Find approximately, by measurement the *difference* in length between the two belts.



Question 1.



Question 3



Question 4.

SECOND YEAR EXAMINATION 1934.

THEORY.

Time allowed—Three Hours.

Answer Question 1 *and four others.*

1. Give an outline of a course of *Practical Work* which you consider suitable for teachers preparing for the examination you are now taking.

2. Indicate instances where familiarity with the properties of metals is essential when a choice of metal has to be made for a piece of work in the school workshop.

3. Show, with the help of a sketch or diagram, a usual type of arrangement used for starting and stopping a machine independently of other machines running on the same mainshaft.

4. Why does the shape of a lathe tool vary when used for doing the same work on different metals. Give the approximate size of angles suitable for the commoner metals and also the speeds.

5. Describe the more advanced processes in forge work which you would include in this branch of metalwork for a class of boys in the middle forms of a secondary school.

6. The three operations or processes in each of the three following sets are similar in some respects. Explain the processes by sets, giving reasons for choosing one of them in preference to the other two for any given job.

(*a*) Chipping, filing, scraping.

(*b*) Drilling, boring, punching.

(*c*) Tinning, plating, lacquering.

PRACTICAL.

Time allowed—Six Hours.

Both tests are to be done.

1. WINDOW FASTENER.

Forge and shape the handle. The double-bend shown in elevation should be done cold and only after the handle has been completely finished by filing.

Braze the $\frac{5}{16}$-in. rod in the plate as shown, then drill and tap it $\frac{3}{16}$-in. Whitworth. (Alternatively, the $\frac{3}{8}$-in. rod may be used and, after brazing, the projecting portion turned down to $\frac{5}{16}$-in.).

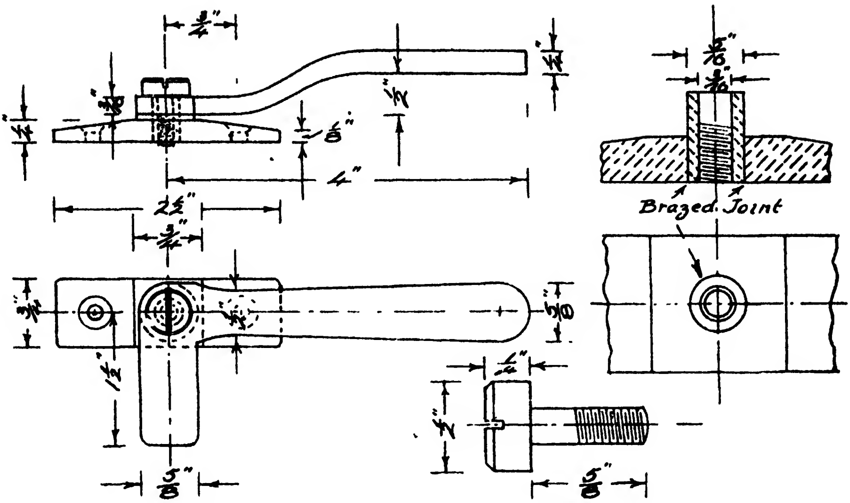
Turn, tap and finish the screw to the given dimensions.

Finally, fix all the pieces, including the washer, together to work smoothly.

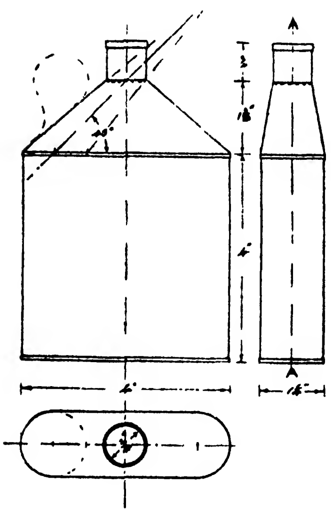
2. Make the flat can to the sizes and shape given.

All joints to be along A—A and they may be of the simple lap type.

The handle is not essential.



Question 1



Question 2.

DRAWING.

Time allowed—Three Hours.

Answer Question 1 *and two others.*

1. Drawings of a simple type of Fly Press.

The half plan is not complete and the whole of the base is not shown in the front elevation.

(The guide piece which carries the slide is shown broken off and is not required for this question).

Draw the side elevation and front elevation complete and project a complete half plan. Scale ½ full size.

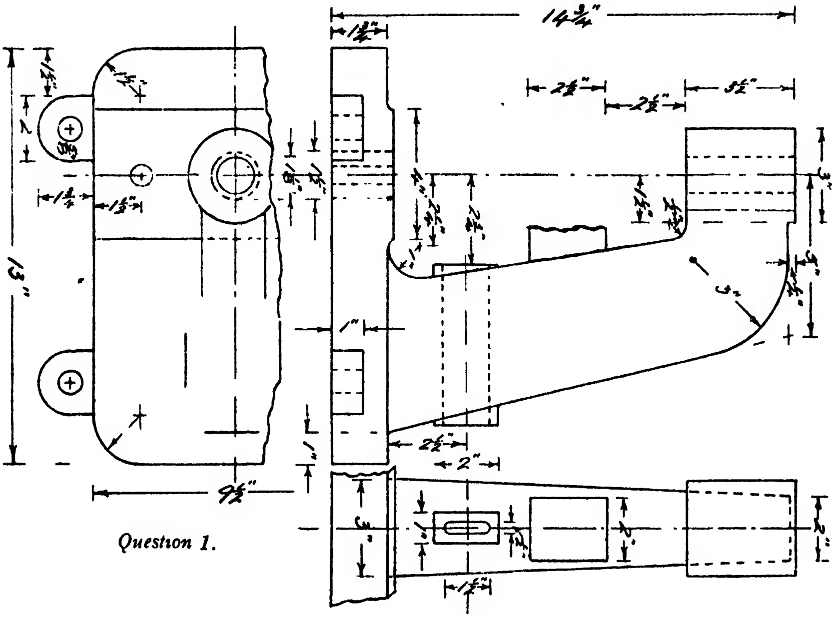
2. Make clear drawings (sketches or otherwise) of the guide piece not shown in Question 1, together with the slide and the usual method of fixing and adjusting.

3. Plan (incomplete) and elevation of a thin sheet metal leg.

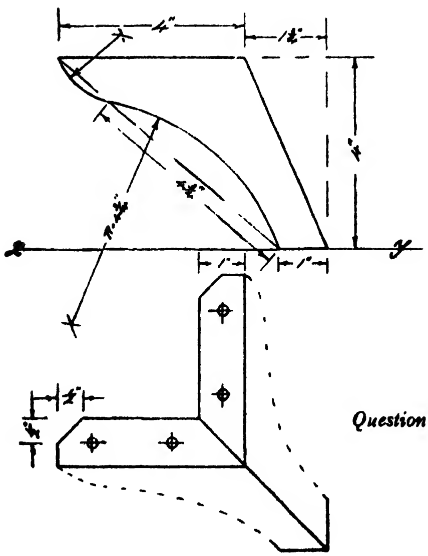
(*a*) Draw the elevation and complete plan. Show clearly your method of obtaining shape of lines shown dotted in plan.

(*b*) Draw the true shape of the piece of thin sheet metal from which the leg is made.

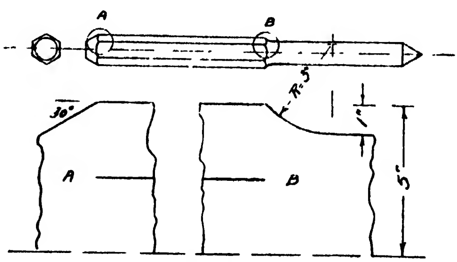
4. Centre punch turned from hexagonal rod. Portions in circles A and B are shown enlarged. Draw these portions to the sizes given and show the lines of intersection between the flat faces and turned surfaces correctly projected.



Question 1.



Question 3.



Question 4.

FIRST EXAMINATION STAGE.
Summer 1938.

THEORY TEST.

Time allowed—Three Hours.
Answer Five Questions.

1. What system would you adopt to ensure that all boys would, as far as possible, have equal opportunities of experience in each branch of metalwork. Assume a fully-equipped workshop.
2. Describe, with help of sketches, *either*
   (*a*) Screw cutting with hand tools, *or*
   (*b*) Drilling with hand tools.
3. Tabulate (or otherwise deal briefly with) the ease, difficulty, or special precautions to be taken when the following operations are being carried out:—*Filing, Tapping, Forging, Bending, Soldering*. The materials to be used are *Cast Steel, Mild steel, Cast iron, Copper*.
4. Sketch a set of 4 exercises increasing in difficulty and introducing fresh operations in non-ferrous sheet-metal work.
5. What are alloys? Why are they made? Give some details of the more common types used in a school workshop.
6. What is meant by:—*Tinning, Drawing down, Plug tap, Vee-block, Annealing, Draw-filing?*

PRACTICAL TEST.

Time allowed—Four Hours.
Two tests only to be attempted.
Test 1 (*compulsory*) *and either Test* 2 *or Test* 3.

Test 1. DRAWER HANDLE.

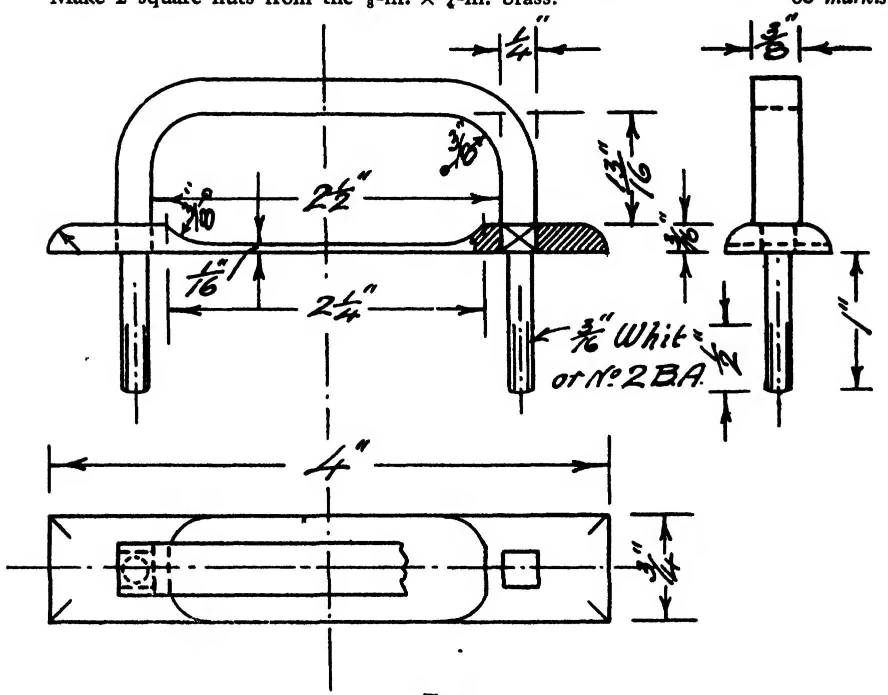
The plate of steel is to be drawn down by forging at the centre and then filed to exact shape.

The handle of brass strip, $\frac{3}{8}$-in. × $\frac{1}{4}$-in.

File both ends to $\frac{3}{16}$-in. diameter for a length of 1-in. and to square section for a length of $\frac{3}{16}$-in. Tap $\frac{3}{16}$-in. Whitworth (or 2 B.A.). Draw file carefully. Bend COLD care being taken to prevent any bruising of surfaces.

Drill and file the 2 square holes in the back plate to fit the handle (a push fit).

Make 2 square nuts from the $\frac{3}{8}$-in. × $\frac{1}{4}$-in. brass. 60 *marks*



Test 1.

Test 2. HEXAGONAL BOX IN TINPLATE.

The sides are of one piece bent at the corners marked " *a* " and butt jointed and soldered from the inside at those marked " *b* " (An ordinary lap joint at one of the " *a* " corners).

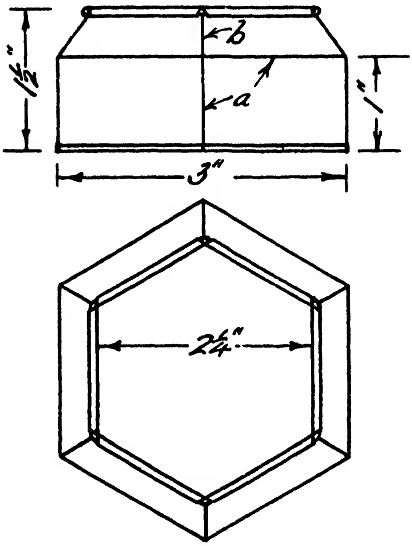
Cut the bottom to size, turn up the edges and solder neatly. Finally wire the top edge.

40 *marks.*

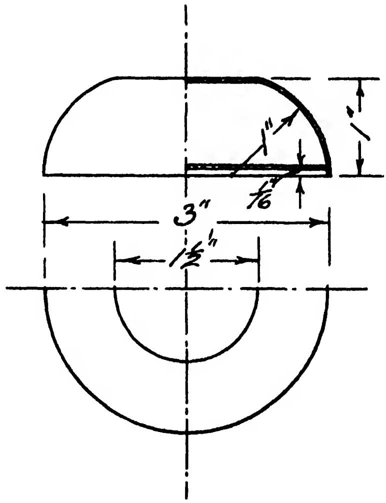
Test 3. ASH TRAY.

The " top " portion may either be " raised " from the solid disc and the hole $1\frac{1}{2}$-in. diameter, cut out afterwards; or the hole may be cut before " raising."
Soft solder the bottom (a flat disc) $\frac{1}{16}$-in. above the bottom edge as shown.
Brighten up the job suitably.

40 *marks.*



Test 2.



Test 3.

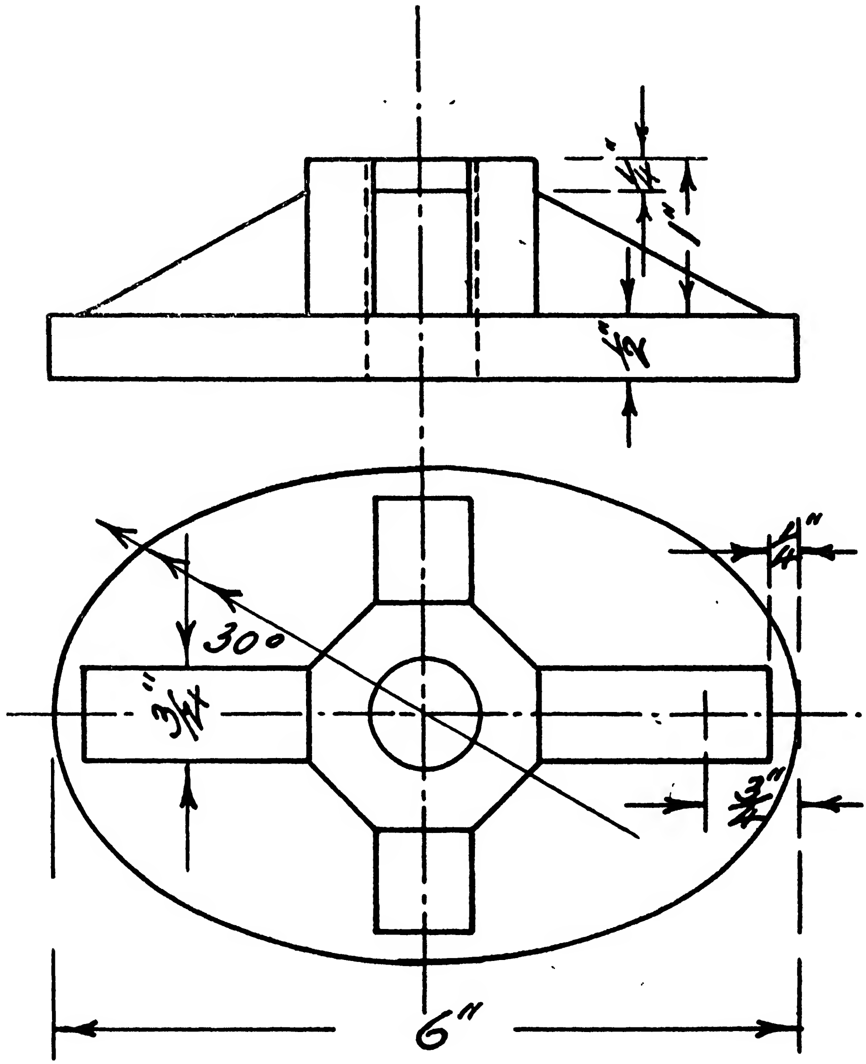
DRAWING TEST.

Time allowed—Three Hours.

Answer Question 1 *and* Two *others.*

Question 1. Plan and Elevation of a Casting.

(*a*) Draw the Plan. (The measurements given for the ellipse are (i.) major axis 6-in. and (ii.) distance of foci from end of axis ¾-in.). Show constructions for this and for octagon of ¾-in. side.



Question 1.

(*b*) Instead of front elevation, draw a centre sectional elevation (on major axis) showing a 1-in. rod screwed half way into the fully threaded hole at the centre.

(*c*) Project a new elevation in direction of arrow (one half of this elevation is sufficient).

Question 2. TEMPLATE FOR MAKING A REGULAR HEXAGONAL VASE IS GIVEN.

Make a simple scale to use for increasing the linear dimensions of the template in the ratio 5 : 6.

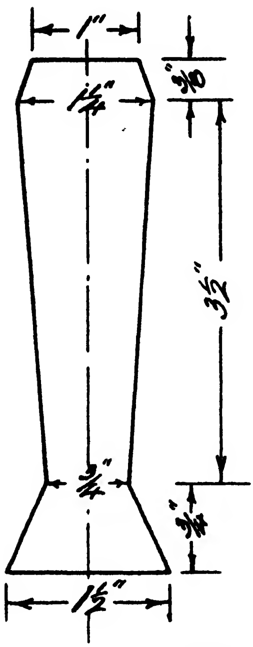
Having drawn the template to this new scale, draw one elevation of the vase to this increased size.

Question 3. DRAW THE DEVELOPMENT OF THE TOP PORTION OF A WATER CAN.

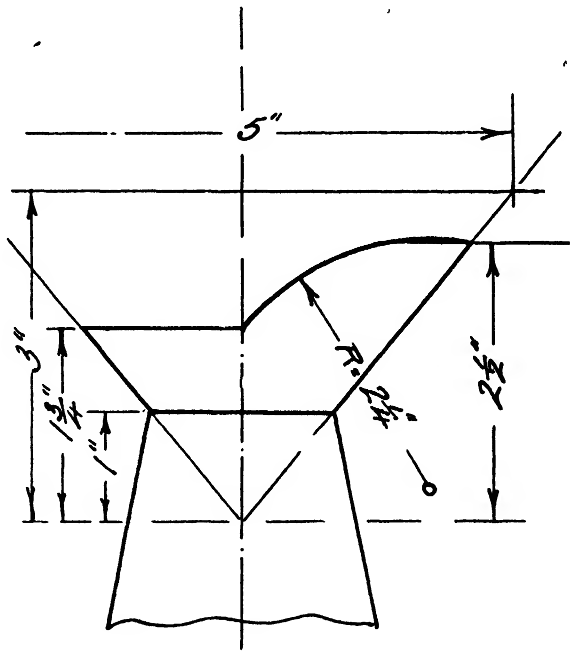
It forms part of an inverted cone 5-in. diameter, 3-in. deep. Draw also a half plan of this top portion.

Question 4. MAKE AN ISOMETRIC DRAWING OF THE CASTING OF QUESTION 1.

Conventional Scale.



Question 2.



Question 3.

FINAL EXAMINATION AND ADVANCED EXAMINATION STAGE.

THEORY TEST.

Time allowed—Three Hours.
Answer FIVE *Questions.*

1. Discuss the relative merits of the two types of work which may be defined as (*a*) Engineering type where accuracy and fit are the chief requirements, and (*b*) Household type where usefulness is not necessarily lost by inaccuracy.

2. Briefly describe the process of screw-cutting in a lathe.
Make a list of instructions suitable for giving to boys engaged on this work, on their own, after a previous class or group demonstration.

3. What are the following? Where and why are they used?
Illustrate your answers by examples from the Metalwork shop.
Multiple thread, Left-hand thread, Buttress thread.

4. Give a short account of the heat treatment of steel with relation to cutting tools of various types.

5. Describe two processes for the prevention of oxidation or tarnishing of brightly finished surfaces which you consider suitable for general adoption in the School Workshop.

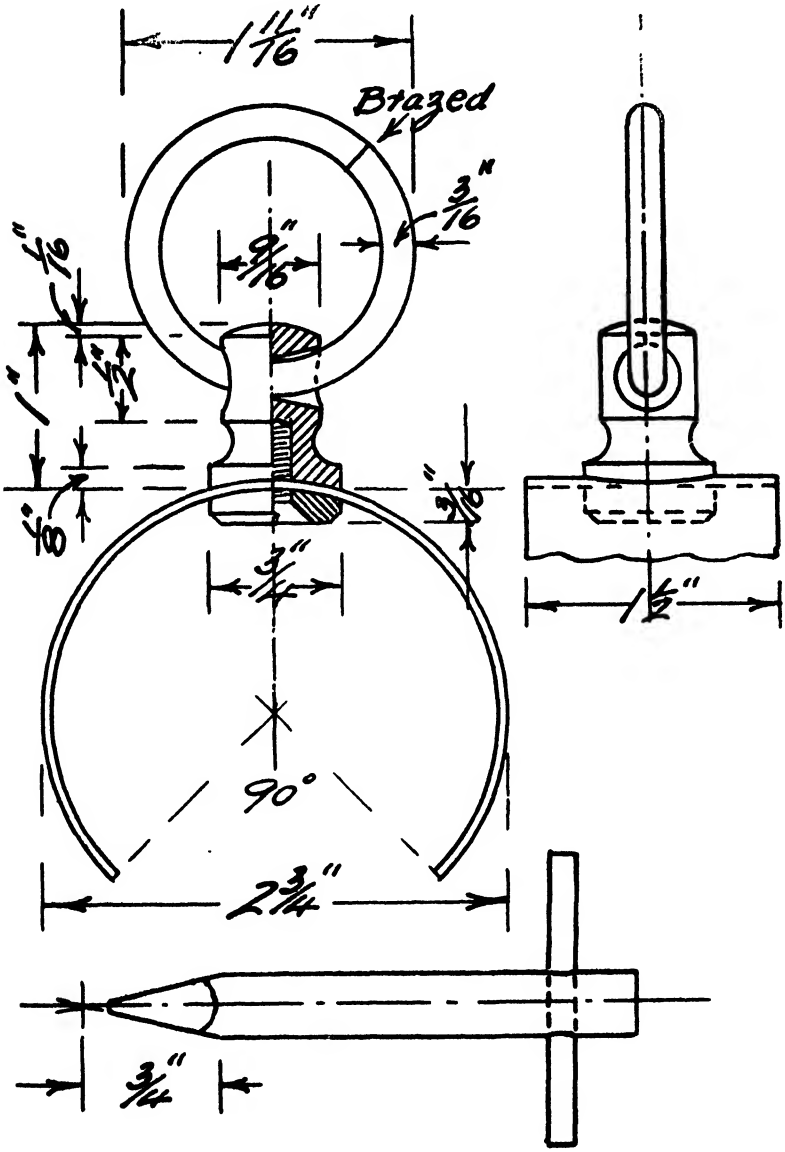
6. Make sketches of FIVE turning exercises. The operations involved to increase in difficulty with each of the five exercises.

7. " Blocks " of the wood, sandbag, lead and pitch types are used in raising and other processes in sheet metalwork and also in Repousse work.

Describe these FOUR types of blocks and briefly explain their construction and special uses.

PRACTICAL TEST.

Time allowed—Six Hours.
TWO *tests only to be attempted.*
Test 1 *(compulsory) and either Test* 2 *or Test* 3.



Test 1

1. (*a*) Coal Tongs. (*b*) Reamer.

The washer inside the spring piece should be turned solid with the piece into which the rihg fits, and then cut off after the hole for the $\frac{3}{16}$-in. screw has been drilled, countersunk and tapped. $\frac{7}{8}$-in. diameter brass supplied for this portion.

(Allow sufficient on the length for sawing off the washer and filing the sawn surfaces to the curvature of the spring piece).

Make the square tapered reamer and, after tempering, use it to countersink the hole for the ring from both sides.

Make the ring and braze the joint as shown. Finally, if you have time, file spring piece to suitable shape, drill and bend to $2\frac{3}{4}$-in. diameter.

60 *marks.*

2. Hexagonal Vase.

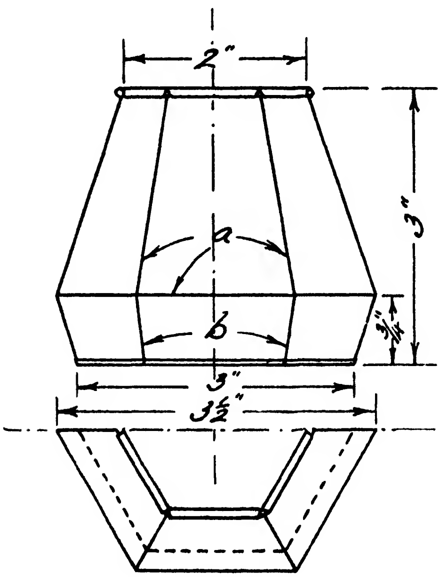
The sides to be cut from one piece of tinplate, bent at the corners marked "*a*" (one plain joint at one corner) and soldered from the inside at the butt joints marked "*b.*"
Solder the bottom turned up lap joint. Wire top edges.

40 *marks.*

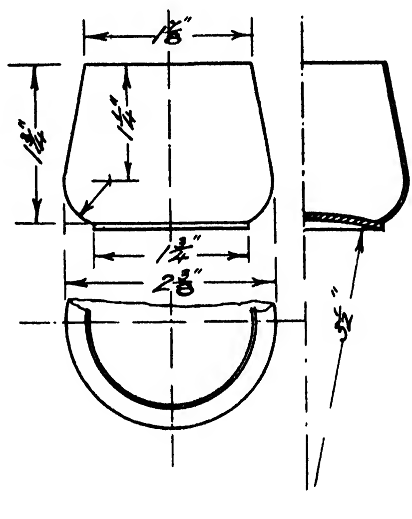
3. Copper Jug.

Make the truncated cone of sheet metal provided. The joint to be brazed.
Round over the bottom edge by hammering, and annealing as required.
The bottom is a disc slightly "dished" as shown and soft soldered to the sides.
Brighten up the job suitably.

40 *marks.*



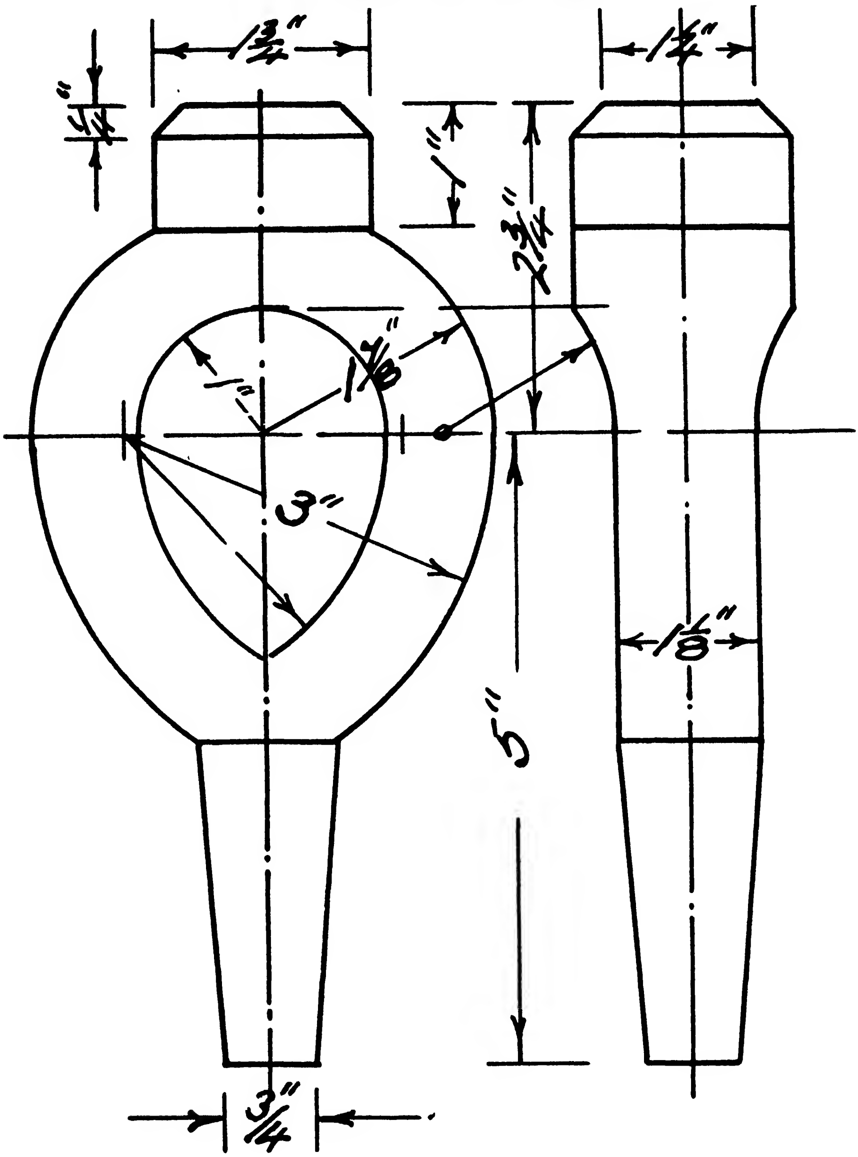
Test 2.



Test 3.

DRAWING TEST.

Time allowed—Three Hours.
Answer Question 1 *and* Two *others.*



Question 1.

Question 1. Lathe Carrier.

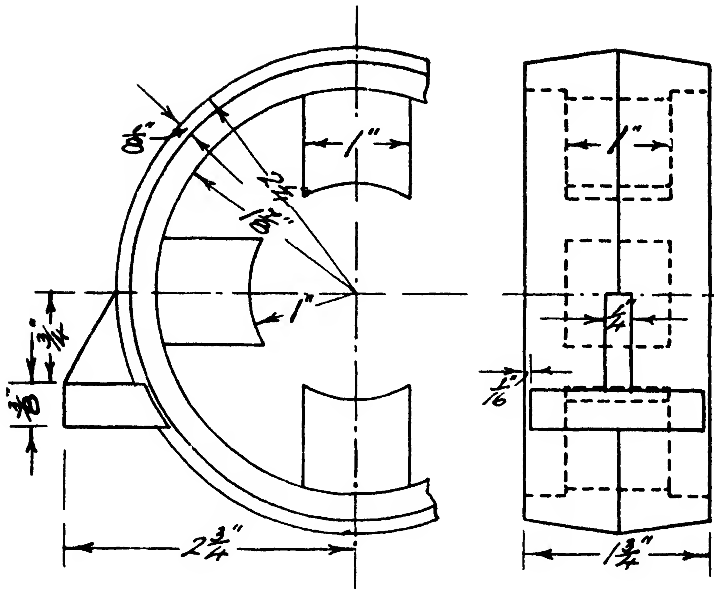
(*a*) Incomplete elevations are given.

The carrier is turned in a lathe to the outline shown in the front elevation.

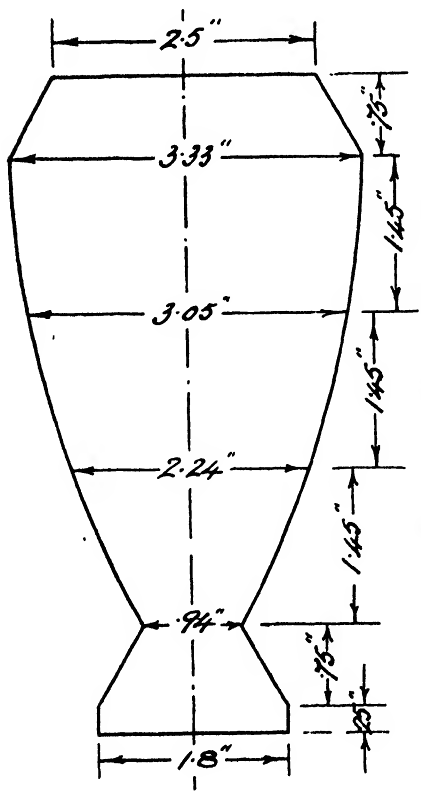
The front and back surfaces are machined as shown in the side elevation.

Complete half the front elevation showing the intersections of the turned surface with the machined surfaces. Full scale.

(*b*) Draw a suitable ¾-in. screw with square thread ⅛-in. pitch. Double scale.



Question 2.



Question 3.

Question 2. CASTING FOR SMALL ELECTRIC MOTOR.

Draw an Isometric Projection of the casting. Conventional scale.

Question 3. TEMPLATE FOR SHEET METAL CANISTER OF REGULAR HEXAGONAL SECTION.

Draw the two (half) elevations of the canister. (It is unnecessary to draw the template for this question).

Question 4. Reproduce (by any suitable means, such as pricking through) the template shape of Question 3 to the size to which it is drawn on the question paper.

Then enlarge your drawing, by a geometrical method, so that the maximum length is 6½-in. and the maximum width 3-in.